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# ENVIRONMENTAL NOISE ASSESSMENT IN LAND USE PLANNING

1999

Ministry of the Environment
Ontario

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Manual for environmental noise assessment in land use planning course.

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# MANUAL FOR

# ENVIRONMENTAL NOISE ASSESSMENT IN

# LAND USE PLANNING COURSE

NOVEMBER 1999

## ACKNOWLEDGMENTS

A large part of this manual has been prepared by extracting material from the Ministry's other noise manuals for environmental noise courses, previously given by staff of the Noise Assessment Unit, Approvals Branch, Ontario Ministry of the Environment. The following documents are acknowledged:

**Manual for Environmental Noise Certificate Course, 1995, 1997**
**Environmental Noise for Environmental Officers, 1990**
**Environmental Noise Assessment in Land Use Planning, 1990, 1997**
**Introductory Environmental Noise Course Manual, 1988**
**Certificate Environmental Noise Course Manual, 1989**

All of the above manuals are out of print.

## COURSE INFORMATION

This manual has been prepared to serve as a training manual for the MOE course Environmental Noise Assessment in Land Use Planning.

### PREREQUISITES

The course is for practising planners, engineers, architects and developers within municipal, provincial and federal governments; for individuals with similar responsibilities within agencies such as the railway companies; and for consultants. High school education or equivalent practical experience is mandatory.

Each participant is expected to bring his/her own calculators and be able to use it for logarithmic calculations.

### DURATION, METHODS AND STUDY REQUIREMENTS

The duration of the full course is three and a half days. The basic course is three days of morning and afternoon lectures, workshops and seminars. The final half day is optional and covers more complex topics.

The text of this Manual will be discussed in detail during the course. The participants are expected to review the day's work in the evening, by themselves.

### EXAMINATION

An examination takes place on the last day.

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# INTRODUCTION

## 1. BACKGROUND

The law concerning noise goes back a number of years. Noise was originally treated as an inconvenience, a nuisance or as an interference with the use of property. In response to public concerns authorities became involved in several areas that address these concerns. These areas include appropriate planning of sensitive uses that utilizes the principles of land use compatibility, planning and approval of new noise sources, and responding to complaints and restraining the activities of noise makers.

The Ministry of the Environment is concerned with the sources of contaminants that may affect the environment as well as land uses that may be affected by the contaminants. The Ministry receives its authority to provide input into the planning process through provisions contained in the *Planning Act*. The Ministry provides comments and recommendations with regard to land use planning on all matters relating to its mandate - the protection, conservation and management of the natural environment.

The MOE also safeguards the environment against noise impacts by assessing planned undertakings. Major undertakings are subject to the *Environmental Assessment Act* and its provisions ensure acceptable noise environment. Other installations require a Certificate of Approval according to the requirements of the *Environmental Protection Act*.

Finally, the *Environmental Protection Act* empowers local municipalities, subject to the approval of the Minister of the Environment, to pass by-laws regulating or prohibiting the emission of sounds or vibrations. According to models developed by the MOE, these municipal by-laws can prescribe maximum permissible levels of sounds or vibration, and prescribe procedures for determining the levels of sounds or vibrations. The MOE models for municipal by-laws are contained in an MOE document, Model Municipal Noise Control By-Law.

## 2. NOISE GUIDELINES

MOE Guideline LU-131, Noise Assessment Criteria in Land Use Planning, outlines the position of the Ministry of the Environment on noise criteria for planning of sensitive land uses. It is intended for use in planning of noise sensitive land uses which are adjacent to facilities such as but not limited to airports, road and rail transportation corridors, industrial facilities, aggregate facilities, major commercial facilities, sewage treatment facilities, and waste sites.

This guideline defines criteria for noise impact assessment of proposed residential or other noise sensitive land uses and specifies procedures for the establishment of sound levels on the site of proposed noise sensitive land uses due to transportation sources (road, rail and air traffic) as well as stationary sources (such as industrial and commercial activities).

The supplementary MOE guideline, Noise Assessment Criteria in Land Use Planning: Requirements, Procedures and Implementation, presents information relating to the details of technical assessment and review of noise impact on planned sensitive land uses. The guideline specifies the conditions under which noise studies may be required, as well as the appropriate assessment methods and procedures.

## TOPIC 1. PLANNING PROCESS

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Explain the main legislation governing land use planning in Ontario;

2. Describe land use planning controls and approval processes; and

3. Explain the roles and responsibilities of municipalities and the province, particularly MOE, in the planning process.

## PLANNING PROCESS

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# PLANNING PROCESS

## 1. PLANNING PROCESS IN ONTARIO

Land use planning affects almost every aspect of life in Ontario. It helps decide where in our communities homes and factories should be built; where parks and schools should be located; and where roads, sewers and other essential services should be provided. Useful information about the planning process in Ontario is available on the MMAH's website at *"www.mmah.gov.on.ca"*. This information also includes a series of "Citizen's Guides", prepared by the Ministry of Municipal Affairs and Housing (MMAH), concerning land use planning in Ontario.

Although elimination or control of the source of pollution is usually the primary objective, there are limits to what is practically and technologically possible. Due to the practical limits of control methods, planners share the responsibility of providing an acceptable level of environmental quality.

The primary legislation governing land use planning in Ontario is the *Land Use and Planning Protection Act* (short form: Planning Act) which is administered by MMAH. The legislation setting out the powers and responsibilities of municipalities includes:

1. Municipal Act.
2. Various acts establishing the regional municipalities.

Other legislation having a bearing on land use planning is plentiful. Examples are:

1. Condominium Act
2. Environmental Protection Act
3. Ontario Water Resources Act
4. Environmental Assessment Act
5. Aggregate Resources Act
6. Conservation Authorities Act
7. Public Lands Act
8. Land Drainage Act
9. Expropriation Act
10. Ontario Planning and Development Act
11. Parkway Belt Planning and Development Act
12. Niagara Escarpment Planning and Development Act

## 1.1 PLANNING ACT

The Ontario Planning Act is administered by the Minister of Municipal Affairs and Housing. Under the Act, the province's role is to administer municipal planning controls and perform approval functions required of the Minister of Municipal Affairs and Housing; to co-ordinate planning activities of municipalities; to look after broad provincial interests, such as the protection of farm land and natural resources; and to give direction and advice to municipalities on land use planning issues.

The Ontario Planning Act sets out the ground rules for land use planning in Ontario, and establishes how land uses may be controlled, and who may control them. The Act provides the basis for consideration of provincial interests related to municipal land use planning, such as the management of natural resources; local planning administration, including planning boards in northern Ontario; preparation of official policies and plans to guide future development; regulation and control of land use through zoning by-laws and minor variances; division of land into lots for sale or development by plan of subdivision or consent; and the rights of Ontario citizens to be informed about planning proposals, to voice their views before the elected municipal council, and to appeal land use planning decisions to the Ontario Municipal Board.

Section 2 of the Planning Act requires that actions or decisions affecting land use planning have regard to matters of provincial interest including the protection of the natural environment, and the health and safety of the population.

Section 3 of the Planning Act enables the province to clarify provincial policies in matters affecting land use planning through the issuance of policy statements. The purpose of policy statements is to enable the province, from time to time, to set down its objectives on matters of planning concern that apply beyond any individual municipality. The statements should assist municipalities in understanding what specific provincial objectives are, and will form part of the framework within which municipalities should plan.

Section 3 of the Planning Act requires that municipalities, in carrying out their own planning functions, "have regard to" these statements. At the same time the OMB, provincial ministries and agencies are also required by the legislation to "have regard to" such statements in carrying out their varied responsibilities.

Depending on the nature of the particular provincial concern, policy statements may be initiated by the Minister of Municipal Affairs and Housing alone, or jointly with other ministers whose responsibilities affect local planning. The Planning Act requires that before a policy statement is approved, the Minister confer with those who are considered to have an interest in the matter.

The Planning Act assigns approval authority for some types of planning applications directly to some municipalities. Where approval authority has not been automatically assigned to municipalities, Section

4 of the Planning Act allows the Minister of Municipal Affairs and Housing to delegate any of his authority, except the authority to approve its own official plan and amendments, to a municipal council. Only upper-tier municipalities are eligible to receive the authority to approve local official plans and amendments. Some municipalities and planning boards may be delegated the authority to approve plans of subdivision, part lot control by-laws, plans of condominium and consents. Once delegation occurs, the municipality or planning board is responsible for all matters normally dealt with by the Minister, including the appeal of any matter to the Ontario Municipal Board (OMB). To find out who is the approval authority, contact the municipality or planning board, or look up this information on MMAH's website.

### 1.1.1 Municipal Plan Review

Since 1996, when the Planning Act was last revised, many municipalities and planning boards have been either assigned or delegated approval authority responsibilities. With their decision-making authority, municipalities and planning boards are responsible for, among other things, "having regard to" provincial interests. This is called Municipal Plan Review (MPR). Municipal approval authorities review planning applications to ensure that provincial interests are identified and protected, without circulating planning applications to provincial ministries such as the MOE. With respect to land use compatibility and in particular noise, for example, municipalities are responsible for identifying whether there is an issue, requesting appropriate studies, usually reviewing those studies, and making a decision on the proposed development accordingly.

The province has undertaken a comprehensive and ongoing training program for municipal approval authorities to ensure that they are able to fulfil their new responsibilities. Provincial ministries now have the more restricted role of providing technical advice and assistance in the interpretation of their own guidelines and policies to municipal approval authorities.

| | | |
|---|---|---|
| *Where a municipality is the approval authority* | ➡ | *Municipal Plan Review* |
| *Where MMAH is the approval authority* | ➡ | *Provincial One Window Planning Service* |

### 1.1.2 One Window Provincial Planning Service

Municipal Plan Review is conducted by municipalities in cases where they are the approval authority under the Planning Act. In cases where MMAH is the approval authority, MMAH provides what is called the "One Window Provincial Planning Service". This is a one-stop service for provincial input, review, decision-making and appeal of planning applications. This one window approach provides a single provincial position which integrates the perspectives of several ministries: Environment; Natural Resources; Transportation; Citizenship, Culture and Recreation; Agriculture, Food and Rural Affairs; and Northern Development and Mines.

The One Window Provincial Planning Service extends to provincial participation on appeals of planning matters to the Ontario Municipal Board. Provincial involvement in a hearing can occur in one of three ways:

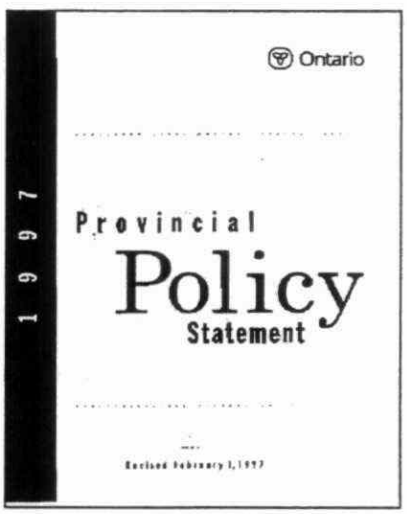
i) The province may be required to defend its own decision as an approval authority, often with the technical assistance of relevant ministries, in the event that the decision is appealed;

ii) The province may appeal or otherwise participate before the Board to protect a provincial interest (e.g. an appeal of a local decision); and

iii) The province may assist a municipal approval authority defend its decision that has been appealed. The province has a range of options to provide municipalities with support at the Board - from advice to technical experts to full party status.

### 1.1.3 Provincial Policy Statement

The Provincial Policy Statement is issued under Section 3 of the Planning Act. It provides policy direction on matters of provincial interest related to land use planning and development. The Provincial Policy Statement includes policies in three areas:




1. Efficient, Cost-effective Development and Land Use Patterns
   - policies for development of communities, housing and infrastructure;

2. Resources

   - policies for agriculture, mineral resources, natural heritage, water quality, cultural heritage and archaeological resources;

3. Public Health and Safety

   - policies for natural hazards and human-made hazards.

Policy 1.1.3.g) deals with land use compatibility, including noise, as follows:

> "1.1.3 Long term economic prosperity will be supported by:
>
> g) planning so that major facilities (such as airports, transportation corridors, sewage treatment facilities, waste management systems, industries and aggregate activities) and sensitive land uses area appropriately designed, buffered and/or separated from each other to prevent adverse effects from odour, noise and other contaminants.
>
> To protect airports from incompatible development:
>
> 1. New residential development and other sensitive land uses will not be permitted in areas near airports above 30 NEF/NEP, as set out on maps (as revised from time to time) approved by Transport Canada; but
> 2. Redevelopment of existing residential uses and other sensitive land uses or infilling of residential and other sensitive land uses may be considered above 30 NEF/NEP if it has been demonstrated that there will be no negative impacts on the long-term function of the airport."

## 1.2 FORMULATION AND APPROVAL OF OFFICIAL PLANS

An Official Plan is a comprehensive statement containing objectives and policies established primarily to provide for the physical development of a municipality or an area that is without municipal organization. Most plans comprise maps and a text. One of the maps is usually a land use plan showing where residential, industrial and agricultural uses are expected to locate. The text outlines development policies pertaining to the land use designations on the map. The Official Plan must be reviewed by Council once every five years.

Official Plans are approved by the Minister of Municipal Affairs and Housing or its assigned/delegated authority. The Official Plan provides the policy framework for zoning by-laws, plans of subdivision,

consents to sever, minor variances, and programs such as capital works. All lower-tier or local Official Plans must conform to the applicable upper-tier plan, i.e. regional, county, district municipality official plan.

As background to its Official Plan, a municipality would normally do an inventory and analysis of the natural environment to help it determine the ability of the planning area to support various land uses. Data and information may be available at the municipal, county/regional, and/or provincial level. Also while preparing a new Official Plan, it is vital to consult early with the public, agencies, and the approval authority. They can provide valuable input and help resolve potential issues. Where MMAH is the approval authority, it will provide the One Window Provincial Planning Service in which, for example, existing data from the various provincial ministries can be made available and draft official plan policies can be reviewed. This includes input to and review of noise policies, using MOE's expertise.

As a guide, an Official Plan should contain a section on environmental policies. These policies should include general environmental quality and protection objectives based on the physical conditions (natural environment) of the planning area. In other sections of the Official Plan, it is desirable that somewhat more specific environmental policies be included to indicate where the general environmental policies apply. For example, a section on transportation should include policies for the evaluation and control of noise. However, the inclusion of noise policies in specific sections of the Official Plan may vary from municipality to municipality.

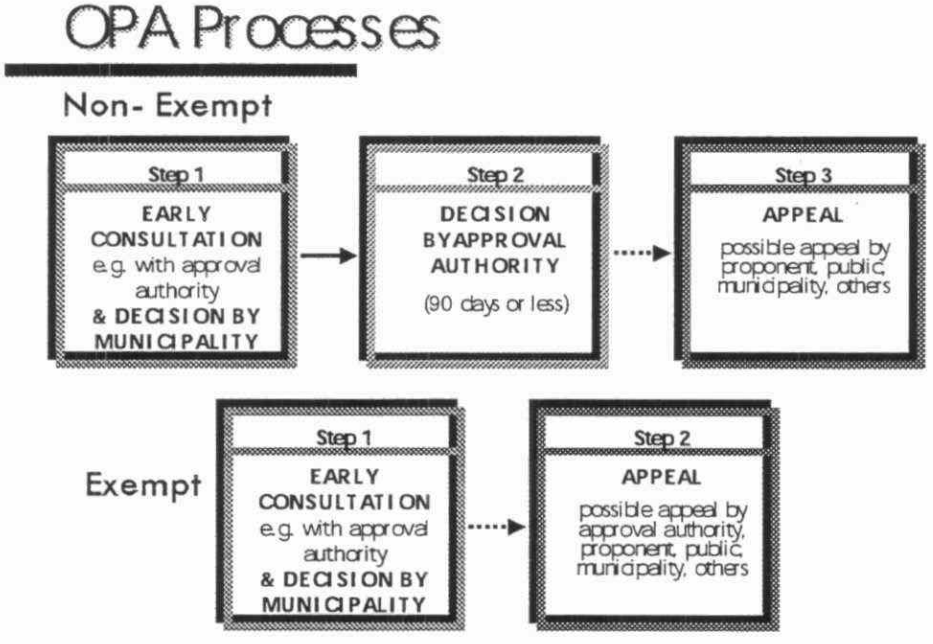
Once the municipality has consulted with affected parties and held at least one public meeting, municipal council may adopt the proposed Official Plan. It is then submitted to the Minister of Municipal Affairs and Housing or the assigned/delegated approval authority for formal approval. The approval authority may consult with others and issue a decision. The decision may be to approve, approve as modified, or refuse to approve all or parts of the Official Plan. A notice of decision is given. Any person or public body may appeal the approval authority's decision to the Ontario Municipal Board (OMB) within the twenty-day appeal period. If there is no appeal, the Official Plan comes into effect. If there is an appeal to the OMB, the OMB's decision is final.

Note: There is a provision in the Planning Act which allows the Minister of Municipal Affairs and Housing to exempt official plans from the formal approval of the approval authority. However, the Minister has chosen not to exempt official plans at this time. Some amendments to Official Plans, however, have been exempted (see below).

## 1.3 AMENDMENTS TO THE OFFICIAL PLAN

Official Plans are the basis for successive and more detailed steps in the municipal planning process. However, due to the changing needs and priorities of certain municipalities, amendments to the Official Plan are often necessary after approval of the Plan. Official Plan amendments may make minor changes to the Official Plan, or may propose major policy changes. Once approved, Official Plan amendments (OPAs) become part of the Official Plan.

Some OPAs are exempt from formal approval by the approval authority. Some are not. Check with the municipality to determine whether an OPA is exempt or not. Non-exempt OPAs follow the same approval process as official plans. Under the exemption system, after council adopts the OPA and gives notice of adoption, any person or public body may appeal council's decision to adopt directly to the OMB within the twenty-day appeal period. If there is no appeal, the OPA comes into effect. If there is an appeal to the OMB, the OMB's decision is final. The exempt OPA process is similar to the zoning by-law amendment process.




## 1.4 MUNICIPAL ZONING BY-LAWS

A zoning by-law is a precise document used by a municipality to regulate the use of land. While Official Plans set out the general, long-range policy framework for future land use, zoning by-laws put those plans into effect and provide for their day-to-day administration.

Unlike the Official Plan, the Zoning By-Law contains very specific and legally enforceable regulations. Any new development or construction that fails to comply with a municipality's by-law is not permitted and would be denied a building permit.

Most municipalities have a comprehensive zoning by-law that divides the entire municipality into land use zones. A detailed map of these zones forms an important part of the written by-law. Within each zone, the by-law specifies the permitted uses (e.g. commercial or residential) and the required standards (e.g. location and size of buildings).

A number of specialized by-laws may be used to control land use. Holding by-laws set out the future use of land or buildings but delay their development until, for example, local services such as sewers and water supplies are in place. Interim uses are usually specified. Before being able to use holding by-laws, municipalities must have appropriate Official Plan holding policies in place. Interim control by-laws are used to place a temporary "freeze" on certain land uses while the municipality is studying or reviewing its land use policies. Such a freeze can be put in place for a year at a time, to a maximum of two years only. Temporary use by-laws zone land or buildings for a specific use for a maximum of three years at a time, with further extensions possible. Increased height and density by-laws allow specific bonuses beyond the standards otherwise permitted, but apply only to developments that provide special facilities or services to the community at large, such as additional parkland or daycare facilities. Before being able to use these by-laws, municipalities must have appropriate Official Plan policies in place, authorizing increases in height or density.

When a municipality decides to prepare a zoning by-law, it must first make adequate information available to the public. Local councils must hold at least one public meeting to allow citizens an opportunity to express their views before a decision is made. Notice of this meeting is given in advance, usually through local newspapers or by mail. Anyone present at the meeting has a right to address the proposal.

The local council may also consult with interested agencies, boards, authorities, or commissions before making a decision. When full consideration is given to all concerns, the council may decide to pass, change or reject the proposed zoning by-law. If changes are made to the proposal, the council must decide whether another public meeting is necessary.

If a person's or agency's concerns cannot be resolved at the municipal level, council's decision can be appealed to the OMB within the twenty-day appeal period. In such cases, the OMB's decision is final.

### 1.4.1 Site Plan Control

Site plan control by-laws are not zoning by-laws. They are used by municipalities to establish areas where site plan control will be applied to complement and refine local zoning. These areas must be described in each community's Official Plan. Site plan control is used to ensure that proposed developments are built and maintained as approved by local councils; set requirements for the quality and appearance of new developments; ensure safe and efficient access for vehicle and pedestrians; ensure adequate provision of certain facilities, such as parking, landscaping and site drainage; and protect adjacent properties from incompatible new development.

## 1.5 DRAFT PLANS OF SUBDIVISION

Draft plans of subdivision are submitted by the applicants, who are usually the owners of the land to be subdivided, or their agents, to the approval authority. The approval authority is responsible for assessing applications for the subdivision of land.

Where MMAH is the approval authority, circulation to the local municipality is undertaken so that the municipality can advise on local issues and the nature of conditions which would be required. All provincial concerns are identified and resolved by MMAH, with other provincial ministries involved only where necessary for technical support. This is an example of the One Window Provincial Planning Service.

Where a municipality or planning board is the subdivision approval authority, it assesses the application both in terms of local and provincial concerns. This is an example of Municipal Plan review. The assistance of provincial ministries may be sought for technical support or to obtain additional relevant information.

The draft subdivision plan will be reviewed for suitability; checked against the Official Plan and Zoning By-Laws; considered in light of topography, road access, water availability, sewage disposal, flood control, effect or quality of subsurface water or nearby streams or lakes, noise and other factors.

"Draft approval" by the approval authority amounts to a commitment to go ahead with the subdivision, once all the conditions of draft approval have been met. Lots may be offered for sale after draft approval, but can be sold only after the plan of the subdivision has been registered. When all the conditions of the draft approval have been met, "final approval" is given and the plan of subdivision is registered in the provincial land titles or registry system.

In most cases of approval of draft plans of subdivision, the developer may be required to enter into a Subdivision Agreement with the municipality to ensure that certain services, such as noise control measures, sidewalks and roads, are provided after the plan has been registered. The Subdivision Agreement may be registered on the title of the property; it legally binds future owners to its conditions.

Any person or public body may appeal the approval authority's decision to draft approve a plan of subdivision or any of the conditions of draft approval to the OMB, within the twenty-day appeal period. The applicant or any public body may appeal the conditions of draft approval at any time before final approval of the plan of subdivision.

## 1.6 BUILDING PERMITS

It may happen that detailed noise control measures cannot be included in the Subdivision Agreement. One reason for this may be that no detailed plans or specifications are available for the residential (or commercial and office) buildings themselves. In this case, it is often possible to include a clause in the Subdivision Agreement which states that the developer/builder is required to have the acoustical consultant certify that the drawings comply with the building specifications (for noise) prior to the issuance of the building permit. The municipality is responsible for issuing a building permit and it is the applicant's formal permission to begin construction. Through the use of building permits, a municipality can regulate the types of construction in the community and ensure that proper building standards are met.

## 1.7 CONDOMINIUM ACT

Condominiums are a form of property ownership in which title to a unit, such as individual apartments in a high-rise building, is held by an individual together with the share of the rest of the property, which is common to all of the owners.

Condominiums can involve a new development, or an existing rental project which is converted to condominium ownership. They can apply to any type of residential building as well as commercial and industrial areas. Vacant lands are not eligible under the current Condominium Act.

The condominium plan is like a plan of subdivision in that it is a way of dividing property. Similarly, the process for condominium plan approval resembles a plan approval for subdivisions, and must be approved by the Minister of Municipal Affairs and Housing or the assigned/delegated authority. Under the current Condominium Act, condominiums are final approved and registered after the buildings are constructed.

Note: At the date of this printing, Bill 38 had received third reading but not been proclaimed. The Bill introduces many changes to the Condominium Act, including new forms of condominium.

## 2. ROLE OF THE MOE IN THE PLANNING PROCESS

The changes which occurred in 1996 have led the MOE to refocus its role in the land use planning process on broader environmental issues of provincial interest through the formulation and promotion of provincial and municipal planning policies. These policies are geared at ensuring the protection of water resources; at promoting effective, efficient and environmentally sound servicing for new development; and to ensure that land use planning decisions do not result in land use incompatibility. These issues also form the basis of the MOE's former role in the review of site-specific planning applications.

This mandate is derived from the Environmental Protection Act (EPA), the Ontario Water Resources Act (OWRA), the Environmental Assessment Act (EAA), and the Pesticides Act. It is further clarified through MOE policies and guidelines, listed in the Reference Section 4.

Whether through comments on local Official Plan policy, or through technical support for site specific planning applications, the MOE's involvement in land use planning is part of the Ministry's preventative approach to protecting the environment. By ensuring that environmental problems are minimized at the earliest possible stage in a development proposal, the need for expensive abatement controls later on is avoided.

Environmental land use planning has a number of advantages. First, it helps prevent pollution problems before they occur. Second, planning allows more options to be considered and the best possible solution to be chosen, before deciding on development details. Land use conflicts, therefore, can be minimized or prevented. Third, it is a cheaper and more effective means of prevention than pollution control. If abatement measures are still required after planning, the amount and expense of the measures can be reduced. The benefits of land use planning bear directly on the MOE's responsibility for environment quality.

## 3. NOISE AND PLANNING

Noise pollution is a by-product of the society's demand for improved transportation and more material goods. The sounds in most urban communities originate from many different sources. Often sounds from transportation systems, local industry, commercial establishments, as well as a large number of other sources such as dogs barking and children playing can be heard. Due to the variety and fluctuating nature of the sounds heard in most urban communities, several descriptors are often required to assess the impacts these sounds may have on the local residents.

The types of sounds which can be controlled through land use planning and thus pertinent to our discussion are those generated by industry/commerce and transportation (i.e. sounds due to road/rail traffic, and

aircraft). Other types of sounds such as the sounds from lawn mowers, construction equipment and so forth can be effectively controlled through noise by-laws.

Recent studies have shown that community noise in general and industrial or transportation noise in particular has at least four major effects on people. First, it can interfere with spoken communication and the ability to enjoy television, radio or recorded material. A second major effect is its interference with relaxation and sleep. Decrease in work efficiency due to loss of attention is its third major effect. Finally, as a consequence of these three identifiable direct impacts, noise causes annoyance with the subsequent loss in the feeling of well being and the enjoyment of one's property.

In extreme cases, noise may cause adverse health effects. Although at present information is simply too sparse to attribute certain health problems to community noise with reasonable certainty, it is known that noise causes stress and therefore contributes to a large number of physical, emotional and mental disorders.

## 3.1 NOISE CONTROL THROUGH LAND USE PLANNING

The following provides an overview of the control of community noise through the planning process. Details on this wide ranging topic are discussed in subsequent chapters.

### 3.1.1 General Procedure

Although noise control measures may be applied at various stages in the development of a community, the general procedure remains essentially the same. After establishing the locations of the noise sources and their sound characteristics, the sound levels at sensitive locations are determined either through measurements and/or through prediction techniques. The severity of noise impacts is determined by comparing the noise level to the Ministry criteria. If impact is substantial, proper control measures are designed depending on cost, practicality and effectiveness.

### 3.1.2 Major Control Mechanisms

The major control mechanisms available at the various stages in the planning of a community include:

Official Plans

Opportunities for the application of effective noise control measures are available at this early stage in the planning process. Major noise control measures which may be applied include:

- spatial separation between sensitive and noise producing land uses and the suitable arrangement of lands within each type of land use;

- policies aimed at protecting planned sound sensitive developments against impacts from existing/future generators of noise; and

- policies aimed at controlling noise emissions from planned industries, commercial establishments, transportation systems and other noise sources such as pits and quarries.

Zoning By-Laws

Noise control measures may be incorporated into a zoning by-law to deal with a site specific situation where a noise problem has been identified. If a re-zoning due to a proposed development is necessary, opportunities exist through the zoning by-law for the municipality to request the implementation of noise control measures.

Plans of Subdivision

In keeping with the requirements by the Planning Act, noise control measures may be applied through the conditions of approval for the proposed subdivision.

Land uses which generate noise, depending on the type of noise and source ownership:

(a) may be subject to the Environmental Assessment Act; or

(b) may require a Certificate of Approval according to the requirements of the Environmental Protection Act.

With regard to noise sensitive developments, various noise control measures are available to achieve acceptable sound levels for the future inhabitants and they include:

- site planning techniques;
- acoustic barriers;
- architectural design - indoor sound levels;
- construction techniques - indoor sound levels.

## 4. REFERENCES

The following MOE guidelines are pertinent:

1. D-1, Land Use Compatibility

2. D-1-1, Land Use Compatibility: Implementation
3. D-1-2, Land Use Compatibility: Specific Applications
4. D-1-3, Land Use Compatibility: Definitions
5. D-6, Compatibility between Industrial Facilities and Sensitive Land Uses
6. D-6-1, Industrial Categorization Criteria
7. D-6-2, Relationship between C. of A. Process and Planning Process
8. LU-131, Noise Assessment Criteria in Land Use Planning
9. Noise Assessment Criteria in Land Use Planning: Requirements, Procedures and Implementation

## TOPIC 2. ACOUSTICS

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Describe the behaviour and nature of sound waves.
2. Define the relationship among frequency, wavelength and speed of sound.
3. Distinguish between spherical and cylindrical wave propagation and give examples of each.
4. Describe and illustrate phenomena of beats, tones, impulsiveness and intermittence.
5. Explain why weighting networks are used in sound measurement.
6. Give the reasons for the use of logarithmic scale in sound measurements.
7. Indicate typical sound levels of some common noise sources in decibels.
8. Add sound pressure levels in decibels.
9. Calculate composite sound levels in decibels as a result of individual noise sources.

# ACOUSTICS

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# ACOUSTICS

## 1. NATURE OF SOUND WAVES

### 1.1 DESCRIPTION OF SOUND

If a person claps his hands, or strikes a hammer or plays a violin, sound is produced. Sound is the auditory perception of a disturbance which travels or propagates in the form of waves similar to waves in water. For the sound to travel or propagate the surface must be in contact with a material medium such as air, water or a solid. Sound cannot propagate in vacuum.

A familiar sight is waves travelling across the surface of water. The action of the water particles is simply to bob up and down like a cork and not to move with the wave. In sound waves the particles of the medium simply oscillate to and fro in the direction of the wave, but again do not actually travel with the wave. The energy in the wave is transferred to more distant parts of the medium by a "chain" reaction.

### 1.2 SOUND PRESSURE

Consider a loudspeaker generating sound as shown in Figure 2.1. It does so by the to-and-fro motion of a diaphragm which in turn transmits this motion to the air adjacent to it. This results in small fluctuations in air pressure which travel outwards. These fluctuations in pressure are picked up by the ear as sound. Note that this pressure fluctuation due to sound is superimposed on the normally existing barometric pressure. The additional pressure due to sound is very small compared with the normal barometric pressure.

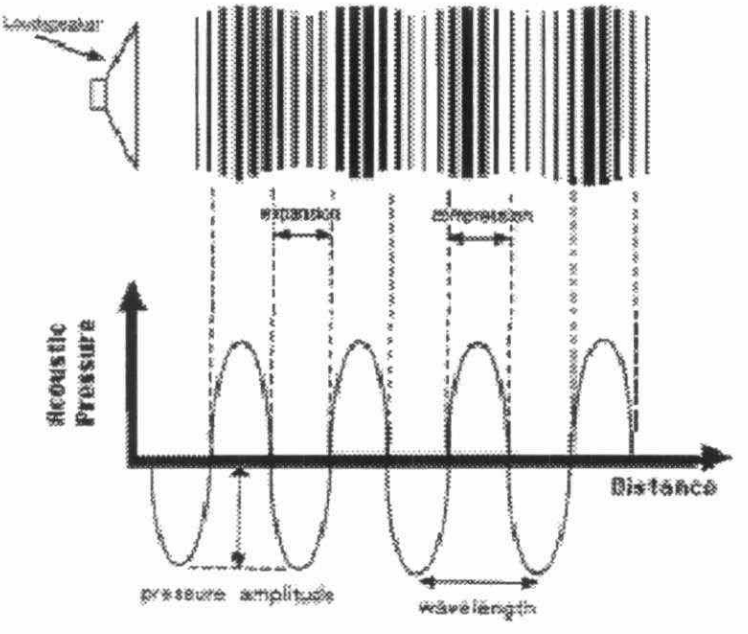


**Figure 2.1 Generation of Sound Waves**

This to-and-fro motion causes alternate compression and expansion of the air. These pressure fluctuations are sensed by the ear as sound.

## 1.3 SPEED OF SOUND

Sound waves do not travel instantaneously. Their speed depends on the medium through which they travel. The speed of sound in water (about 1500 m/s) is much higher than the speed of sound in air. The speed of sound in air increases with temperature - the increase is proportional to the square root of temperature. At 20°C, for example, the speed of sound in air is approximately 343 m/sec.

Example

Although lightning and thunder are generated simultaneously during a thunderstorm, the observer first notices the lightning and only later hears the thunder. The delay is caused by the time needed for the sound to travel from the thunderstorm location to the observer. (The light due to the lightning can be considered to travel the distance almost instantaneously.)

# 2. FREQUENCY, WAVELENGTH AND SPEED OF SOUND

## 2.1 FREQUENCY

Consider the earlier example of the loudspeaker (refer to Figure 2.1). When the diaphragm of the loudspeaker moves to and fro, pressure fluctuations in the form of sound waves are generated. The number of times every second the air experiences these pulsations or fluctuations is known as the "frequency of the sound waves". Obviously the frequency of the sound waves generated is the same as the frequency at which the diaphragm moves to and fro.

The frequency of sound waves is expressed in "cycles per second". Cycles, in this case, refer to the pulsations of air due to sound waves. In noise control work, a more commonly used unit is "Hertz" (Hz). "Cycles per second" and "Hertz" are the same.

Example

If the loudspeaker diaphragm moves to and fro 125 times every second continuously, the frequency of sound waves thus generated will be 125 cycles per second or 125 Hz.

All sounds can be related in terms of frequencies. Generally, most of the every day sounds are a mixture of different frequencies, and the human ear is capable of detecting sounds in the approximate frequency range 15 Hz to 15,000 Hz (or 15 kHz). The ear's sensitivity is not uniform or "flat" over this range, the

sensitivity reducing rapidly at the extremes of the frequency range. The sensitivity of the ear to frequency plays an important role in the noise control field.

## 2.2 WAVELENGTH

The distance between two successive waves is defined as the wavelength. When we talk about the wavelength of a sound wave, we refer to the distance between two successive points, where either the compression or the expansion is maximum (also indicated on the diagram, Figure 2.1). The wavelength is not usually directly measured but can be determined as shown in the following section.

The wavelength is given by the frequency and the speed of the sound:

**wavelength = speed of sound/frequency**

If the speed of sound is expressed in metres per second, and the frequency in Hertz, the wavelength will be in metres.

Example

In air, the speed of sound at 20°C is 343 m/sec.

| | | | |
|---|---|---|---|
| For a frequency of 100 Hz: wavelength in metres | = 343/100 | = 3.43 m | |
| For a frequency of 500 Hz: wavelength in metres | = 343/500 | = 0.686 m | = 68.8 cm |

It is to be noted that the sound frequency increases as wavelength decreases.

When measuring sound in the immediate vicinity of sound sources outdoors, a knowledge of wavelength helps in selecting the best measurement locations. The distance between measurement location and the source should ideally be much larger than the wavelength corresponding to the frequency of interest. At the other extreme, high frequency sound (having a short wavelength) is not directly measurable when the diameter of the microphone exceeds the wavelength of the sound. The latter is an example of diffraction of sound, the ability of sound to "bend" around obstacles. The amount of this bending is again related to wavelength, with the amount of bending increasing with wavelength.

## 2.3 TONES, BEATS, IMPULSIVENESS, INTERMITTENCE AND INTRUSION

(a) Tones: Tones are sound waves, at a single frequency. In general, they are noisier than broad band sounds at the same sound pressure level. Examples of tonal sound sources are circular saws, transformers, sirens, etc.

(b) Beats: Beats are cyclic (pulsing) variations of sound level due to the interaction of two tones at almost the same frequency. Examples of beating noise sources are two machines operating at closely the same speed.

(c) Impulsiveness: Sounds are said to be impulsive if they occur for a time of less than one second. Typical sources of impulsive sound are drop forges, barking dogs and pistol shots.

(d) Intermittence: A sound is said to be intermittent if it is not continuous but remains on for periods greater than one second. Typical examples of intermittent noise sources are aircraft flyover, automobile pass by and train pass by. (See NPC-104 for adjustment for Intermittence.)

## 3. TYPES OF SOUND WAVES

Sound travels in the form of waves. There are basically three types of sound waves:

- Spherical
- Cylindrical
- Plane

The type of wave generated depends upon the sound source. The sound waves from a loudspeaker at a distance of about 15 m will be of the spherical type. On the other hand, when we think of the noise from freely flowing traffic on a highway, the noise comes from a very large number of (moving) point sources. It can be shown that the sound from a whole string of point sources gives rise to waves which spread in a cylindrical fashion, the line or string of sources, being the axis of the cylinder. At very large distances from a source (in comparison to the size of source) spherical and cylindrical waves are very similar to plane waves and may be considered as such. Examples of spherical and cylindrical waves are shown in Figure 2.2.

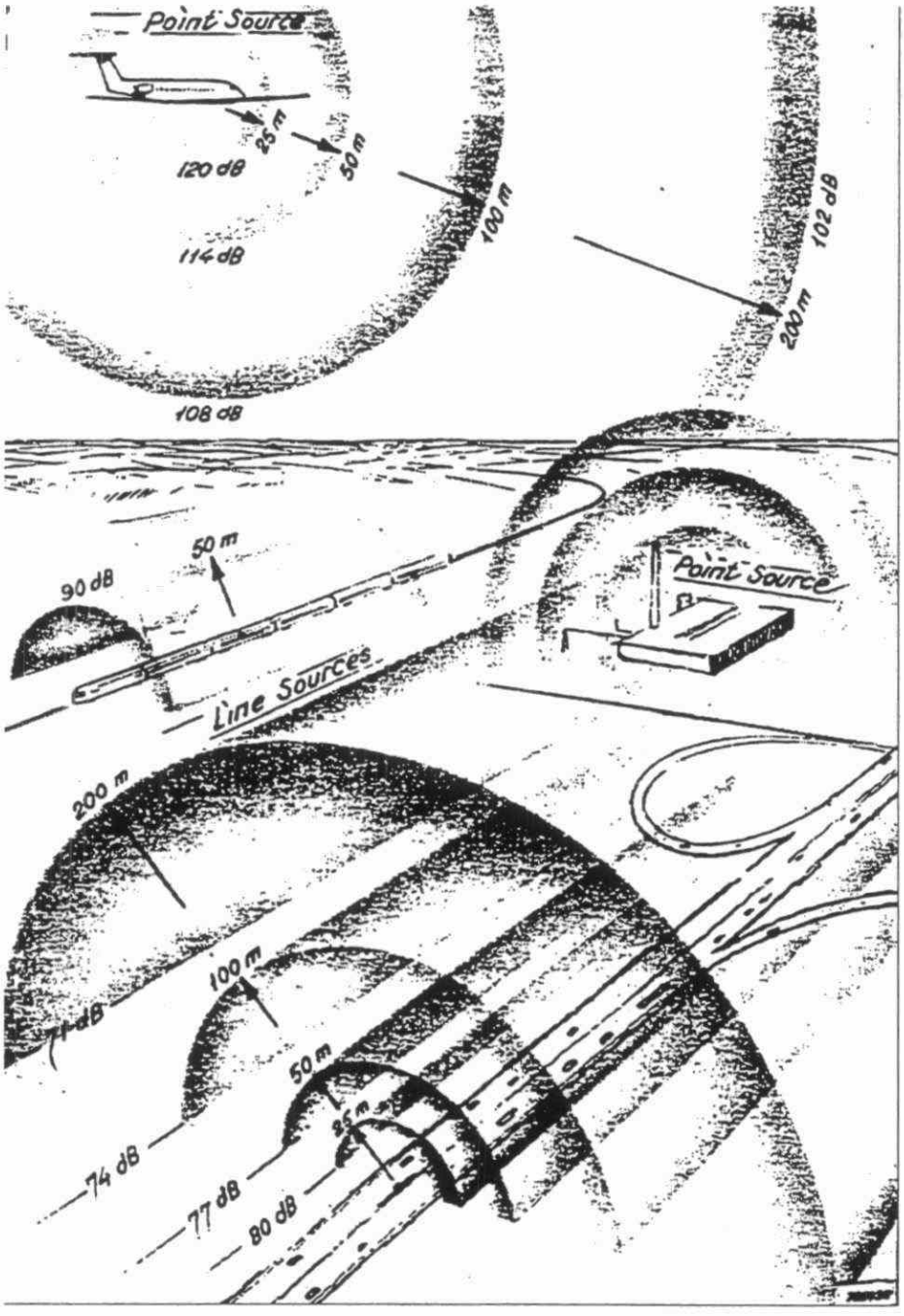


**Figure 2.2 Examples of Point and Line Sources**

## 4. LOGARITHMIC SCALE: DECIBELS

### 4.1 RANGE OF SOUND PRESSURE VALUES

The ear can respond to an amazingly wide range of acoustic pressures. In everyday life we may encounter acoustic pressures such as generated by rustling leaves and the acoustic pressures of a roaring jet engine. The acoustic pressure of the latter example may be one million times that of the former. In between these two extremes lay all the familiar sounds of modern life, e.g. traffic, bird songs, roadworks, etc.

Experience has shown that the square of the acoustic pressure rather than the pressure itself is a better descriptor of the acoustic response of the ear to sound. The square of the pressure is related to the acoustic power.

### 4.2 DECIBEL DEFINITION

The decibel scale of measurement is widely used in various branches of electronics as well as acoustics.

Sound may be described by the amplitude of the pressure fluctuations. The human ear can detect an amplitude change of as little as 20 millionths of a Pascal (20 μPa). This is so small that the ear drum is deflected a distance of less than the diameter of a single hydrogen molecule. The ear is also capable of tolerating amplitude fluctuations a million times greater than this. Thus if we measured sound in μPa, we would end up with some quite large, unmanageable numbers. To avoid this problem, the decibel scale is used. The notation of the decibel is dB.

The decibel is not an absolute unit of measurement. It is a ratio between a measured quantity and a reference level. The **dB** scale is **logarithmic** and uses the hearing threshold of 20 μPa as the reference. This is defined as **0 dB**. When we **multiply** the sound pressure in Pa by 10, we **add** 20 dB to the dB level. So 200 μPa corresponds to 20 dB, 2,000 μPa to 40 dB and so on. Thus the decibel scale compresses a range of a million into a range of only 120 dB. The **sound pressure levels (SPL)** in dB and Pa of various familiar sounds are shown in Figure 2.3.

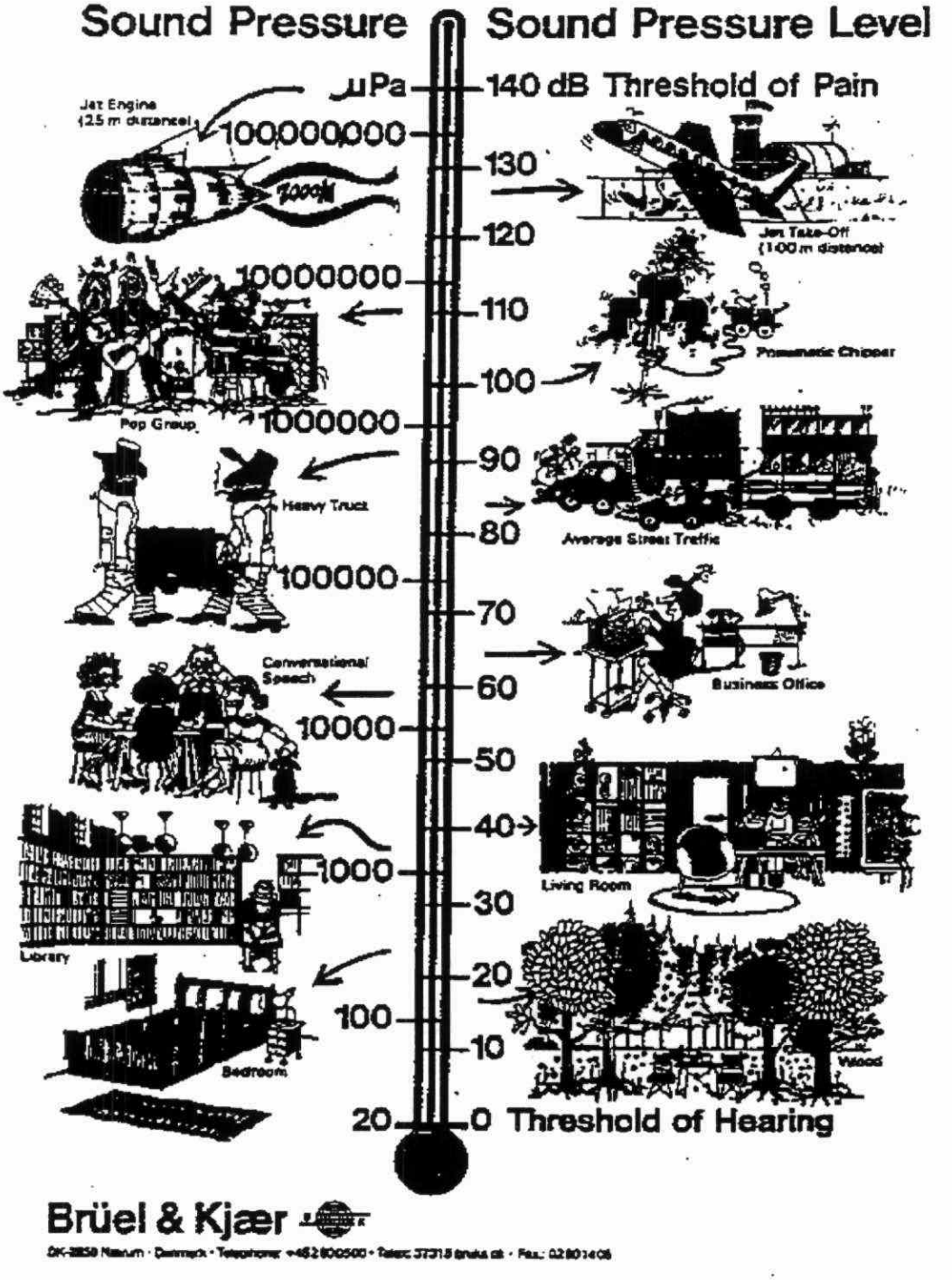


**Figure 2.3 Typical Sound Pressures and Sound Pressure Levels**

One useful aspect of the decibel scale is that it gives a much better approximation to human perception of relative loudness than the Pascal scale. This is because the ear reacts to a logarithmic change in level, which corresponds to the decibel scale where 1 dB is the same relative change everywhere on the scale.

The decibel scale is a power scale and gives a comparison between power related quantities. When quantities are compared using the decibel scale, the comparison is referred to as a "Level".

Definition

The Sound Power Level (PWL) or $L_W$, of a noise source is defined as:

$$L_W = 10 \log \left[ \frac{W}{W_{ref}} \right] dB$$

where W is the acoustic power output of the source in watts, and $W_{ref}$ is the standard reference power of $10^{-12}$ watts. In all likelihood W will be greater than the very minute value chosen for $W_{ref}$ and so all sound power levels will be a positive number of dB.

Also, the square of the acoustic pressure is related to the acoustic power output so we may now define SPL, or $L_p$, at some observer as:

$$L_p = 10 \log \left[ \frac{P^2}{P_{ref}^2} \right] dB$$

where, P is acoustic pressure of the sound waves, in micro Pascals, μPa and $P_{ref}$ is the standard reference pressure of 20 μPa, which corresponds to the threshold of hearing.

### 4.2.1 Point Source

A point source can be imagined as being a point suspended in space radiating sound equally in all directions. It can be proven that **as the distance from a point source is doubled, the sound pressure level is reduced by 6 dB.**

### 4.2.2 Line Source

A line source can be imagined as an infinitely long line (eg. highway) radiating sound equally in all radial directions. Physicists have shown that **if the distance from a line source is doubled the sound pressure level is reduced by 3 dB.**

Example

A sound level of 65 dB was measured at 10 m distance from a line source. The sound level at 30 m is required.

| | | |
|---|---|---|
| Let $L_{P1}$ | = | 65 dB measured at $r_1 = 10$ m |
| $L_{P2} - L_{P1}$ | = | $10 \log [ r_1/r_2 ]$ |
| $L_{P2} - L_{P1}$ | = | $10 \log (10/30)$ |
| | = | -4.8 dB |
| Then $L_{P2}$ | = | 65 - 4.8 |
| | = | 60.2 dB |

## 4.3 ADVANTAGE OF THE DECIBEL SCALE

The decibel scale is commonly used in electronics and acoustics for the measurement of power related quantities. An advantage of the decibel scale is that the unwieldy large range of numbers which result from using a linear pressure scale are replaced by a much smaller range.

Another feature of the scale is that for each tenfold increase in power, the SPL at an observer increases by 10 dB. If we increase the power output from $10^{-11}$ W to $10^{-10}$ W or from 1 W to 10 W we get, in each case, an increase of 10 dB despite the fact that the actual change or absolute change in power output in the two cases is quite different. This is actually of value because if we listened to these changes in level, approximately the same subjective response would be obtained - we would say that in each case the noise had doubled in loudness from its former value. That is, the increase in loudness appears the same.

## 4.4 WEIGHTING

The ear's response to sound is not linear over the audible frequency range (15 Hz - 15,000 Hz). In order to satisfactorily describe human perception and response to sound, a sound level meter is usually filtered or weighted across the audible frequency range in a manner analogous to response characteristics of the ear. This is **A-weighting**. The values of sound pressure level weighted by the A-weighting network are given **dBA**. (If the sound pressure levels are taken using linear (un-weighted) response characteristics, the values are quoted in dB.)

Sound pressure levels of common noise sources are measured using a sound level meter. A simple sound level meter is capable of measuring the "linear sound pressure level" in dB and the "A-weighted sound pressure level" in dBA. It also uses two averaging time weighting characteristics: fast and slow.

## 4.5 ADDING SOUND PRESSURE LEVELS IN DECIBELS

SPLs cannot be simply added; rather, they must be combined accounting for the logarithmic nature of the dB scale. When sounds from separate sources are received simultaneously, the ear responds to the sum of their individual power contributions and not to the sum of their pressures (or sound pressure levels in dB). In order to combine the individual SPLs in dB, conversion to pressure squared terms must be performed, which involves determining the antilog of 1/10 of the SPL. Ten times the logarithm of the sum of the antilog terms gives the resultant SPL.

In mathematical terms, if the sound pressure level due to Source 1 is $L_{P1}$, the sound pressure level due to Source 2 is $L_{P2}$ and the sound pressure level due to Source N is $L_{PN}$, then the resultant SPL, $L_{PR}$ is:

$$L_{PR} = 10 \log [\ 10^{\frac{L_{P1}}{10}} + 10^{\frac{L_{P2}}{10}} + \ldots + 10^{\frac{L_{PN}}{10}}\ ]$$

This expression may be used to combine the SPLs due to two or more sources.

### 4.5.1 Addition of Decibels - Nomograph Method

The nomograph given in Figure 2.4 provides a quick, simple and practical method for combining pairs of decibels. The steps involved are outlined below:

Step 1: Take the difference in dB between the two levels which are being added together.

Step 2: Enter this difference on the chart at the bottom of the scale, and look up the corresponding number on the top of the scale.

Step 3: Add the number so obtained to the higher sound level (louder sound of the two).

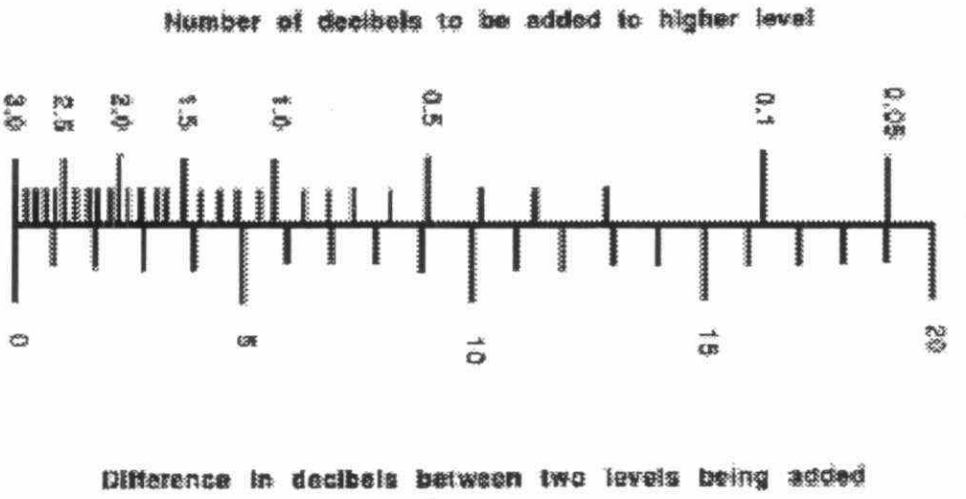


**Figure 2.4 Nomograph for Adding Sound Pressure Levels in Decibels**

Should more than two SPLs need to be combined, then any two levels can be replaced in the summation by their equivalent found by the combination process.

Example

Find the resultant of the following sound pressure levels 60 dB, 54 dB and 65 dB.

Consider first 60 dB and 54 dB.

Step 1: the difference is 6 dB
2: from the chart the corresponding number is about 1 dB
3: adding 1 to the higher SPL we get 61 dB

So the result of combining 60 dB and 54 dB is 61 dB.

Consider now combining 61 dB (i.e. 60 dB and 54 dB) and 65 dB.

Step 1: the difference is 4 dB
2: from the chart the corresponding number is about 1.5 dB
3: adding 1.5 dB to the higher we get 66.5 dB

So the effective SPL due to the three individual SPLs is 66.5 dB. The result is independent of the sequence in which the SPLs are combined.

Note from the nomograph method:

(a) two levels will not result in more than 3 dB adjustment to the higher level;

(b) when two levels differ by 10 dB or more, their resultant SPL is less than 0.5 dB greater than the higher of the two levels; and

(c) very roughly, for quick calculations, you may use:

| DIFFERENCE BETWEEN TWO LEVELS, dB | ADD TO HIGHER LEVEL, dB |
|---|---|
| 10 | 0 |
| 6 | 1 |
| 2 | 2 |
| 0 | 3 |

which can be memorized and interpolations made by constructing a graph.

## TOPIC 3. ANALYSIS OF NOISE

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Define $L_N$, $L_{100}$ ,$L_{90}$ ,$L_{50}$ ,$L_{10}$ ,and $L_1$ .
2. Explain the concept of converting a time-varying noise level to a continuous energy equivalent level.
3. Define $L_{eq}$ .
4. Discuss the usefulness of $L_{eq}$ versus $L_{90}$ , $L_{50}$ , $L_{10}$ and $L_1$ as noise descriptors.
5. Outline the trade-off relationship of time versus sound level.
6. Discuss the importance of measurement duration in noise measurements.
7. Transform the $L_{eq}$ values measured during one time interval to different time durations.

## ANALYSIS OF NOISE

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# ANALYSIS OF NOISE

## 1. INTRODUCTION

The assessment of noise impact of proposed projects or activities necessitates the acquisition of a number of critical pieces of information. The different pieces of information are used in judgements and decisions regarding associated costs versus benefit, the degree of noise control and the feasibility of noise mitigating techniques. In the field of noise analysis the required information is usually centred around the physical attributes of sound.

The main objective of noise analysis is to relate the physical attributes of the noise environment to measures of human response or criteria of acceptability. Many of the physical attributes and parameters of sound were outlined in the previous chapter. The useful relationships between the physical exposure and noise impact are usually obtained by measurements, computation and by the use of various noise descriptors. A noise descriptor is a physically measurable quantity such as Sound Pressure Level in dB and the descriptor is used to scale the impact numerically.

The noise impact can be described by a variety of descriptors. Some of these descriptors are presented in this chapter. The rationale for choosing the descriptors, the definition of the descriptors and their applications are also presented.

## 2. TIME VARYING NATURE OF NOISE

Many noise sources do not produce noise of a steady nature. Noise sources such as traffic, construction sites and radios produce noise levels which are time-varying, often between very wide limits. The fluctuating nature of the noise is evident in a continuous record of the sound level as illustrated in Figure 3.1. The figure represents a time history, i.e. the sound levels are recorded as a function of time.

In any typical community, the lower noise levels will be present for a major portion of the time and will consist of natural sounds such as leaves rustling, flowing water, bird or animal noises. These noises are often accompanied, or perhaps dominated, by distant traffic noise or steady industrial noise. The next higher noise levels will be present for shorter duration and be generated by such sources as nearby highways and industry. Increasing again in level, and decreasing in duration, local traffic would contribute next to the sound pattern. Trucks and trains would have higher levels but are present only for short periods of time. Sources generating even higher levels are children shouting, dogs barking and even thunder, all of which are fortunately only present for very short periods of time. It is, of course, difficult to generalize

the sound level variation with time in a community, but it can be judged from the example given that, as the sound level increases, then it is present for shorter periods of time. This trade-off relationship between level and time duration is generally typical of most noise situations.

## 2.1 RANGE OF VARIATION IN SOUND LEVELS

To give some idea of the possible variation of sound levels with time, consider the two extreme situations; in the first case the source is a busy freeway and at all times the noise climate is dominated by the free flowing traffic. Typical variation in the sound level is 10 to 20 dB.

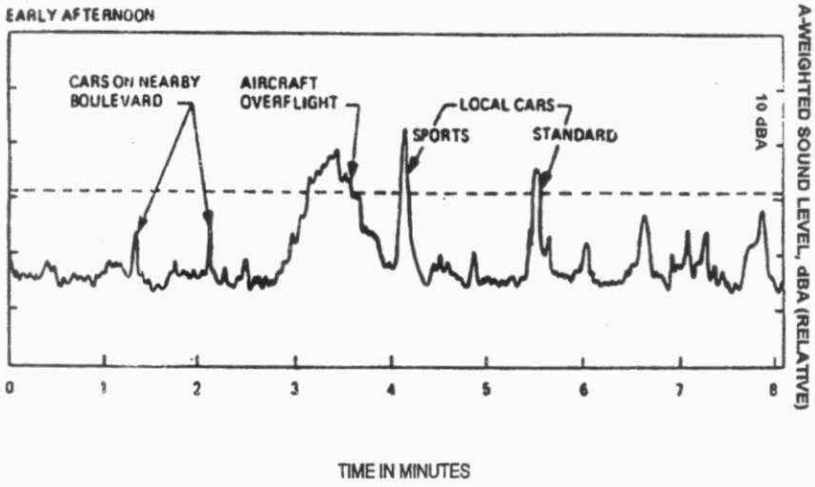


**Figure 3.1** **Representative graphic time history of sound level as sampled in an urban area. Dashed line represents the equivalent energy concept.**

At the other extreme, the source is a "minor" railway track. At night with no train pass-bys the sound level would be very low, typically 35 to 40 dBA in quiet surroundings. However, as a train passes, the sound levels increase up to 90 dBA. The sound level range is about 55 dBA and specialized instrumentation may be required if acoustic measurements are to be conducted.

## 2.2 THE LIMITATIONS OF THE SOUND LEVEL METER

It was pointed out earlier that noise levels vary from 10 to 60 dB between quiet and noisy periods, depending on the type of noise source. A simple sound level meter is usually not sufficient to measure such unsteady noises. If a sound level meter needle shows a range of deflections greater than 3 dB, then a single, eyeball-average sound level will not accurately reflect the noise environment. Many noise situations will produce deflection ranges greater than 3 dB, making the simple sound level meter unsuitable for noise measurement.

A further problem may occur with analog sound level metres some of which can only display sound levels within discrete ranges of 10 to 15 dB. Even though a sound level meter may be suitable for noise analysis, its limited scale range does restrict the use of the instrument.

## 2.3 SERIES OF NOISE MEASUREMENTS

The simple sound level meter can be used for the assessment of non-steady noise by taking single sound level measurements at certain regular intervals (say 10, 20 or 30 seconds) over a specified measurement duration. Assume that a sound level meter was used close to a busy highway, where the variation is only 10 to 20 dB. Sound level readings were taken over a period of 8 minutes, resulting in 66 single sound level measurements. The results were rounded off to the nearest A-weighted decibel and entered into the graph (histogram) in Figure 3.2; each event is representative of one sound level reading.

The histogram provides a useful picture of the whole variation of the noise level over the eight minute period. The sound level never fell below 65 dBA. The sound level was steady for a long time at 70 dBA, this level probably being associated with individual car pass-bys.

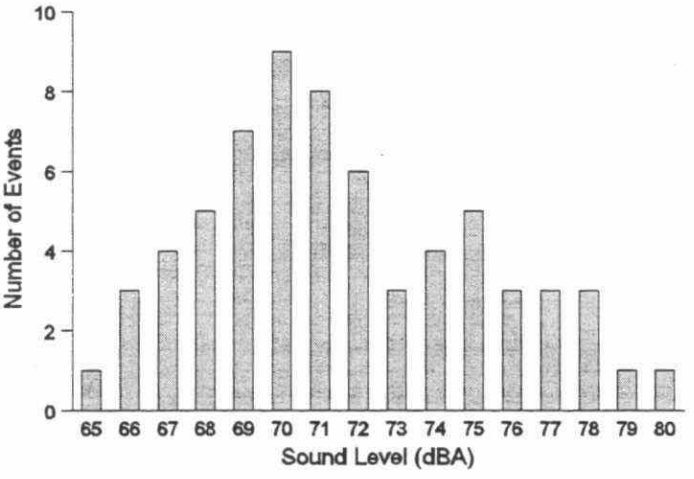


**Figure 3.2 Typical histogram of sound level measurements adjacent to a freeway**

A second most prominent sound level occurred at 75 dBA which probably represents individual truck pass-bys that would be less frequent than the cars, but at a higher noise level. The maximum sound level recorded was 80 dBA. Thus, the histogram provides a useful picture of the noise variation over the 8 minute period. The histogram is a diagrammatic representation of the statistical distribution of the sound level variation during the specified time period.

## 3. STATISTICAL SOUND LEVELS

Although time histories such as the one shown in Figure 3.1 are quite illustrative, a more convenient way to describe fluctuating environmental noise is to adopt a purely statistical approach that takes into consideration the total time or proportion of time the sound of interest is present at various specific levels.

The time varying sound level data can be represented in the form of a histogram, Figure 3.2, or a cumulative distribution curve, each of which denotes levels of noise which are exceeded for given percentages of the time over given periods of observation, or, conversely, the proportion of time certain noise levels are exceeded. The relevant statistic is generally expressed as a noise level, $L_N$ , which is

exceeded for N percent of the time. An example of a statistical distribution of time-varying urban noise is illustrated in Figure 3.3.

## 4. DEFINITIONS AND USE OF $L_N$ , $L_{100}$ , $L_{90}$ , $L_{50}$ , $L_{10}$ and $L_0$

We have just seen that a cumulative distribution is a plot of the percentage of time for which certain sound levels were exceeded. In order to extract useful information from the plot, very often the reverse question "What level was exceeded for a certain percentage of the time?" is presented. For instance, it may be required to know what level was exceeded for 10% of the time. Looking at the statistical distribution, we see that the level exceeded for 10% of the time was 82 dBA. Such levels are often known as $L_N$ values, defined as follows:

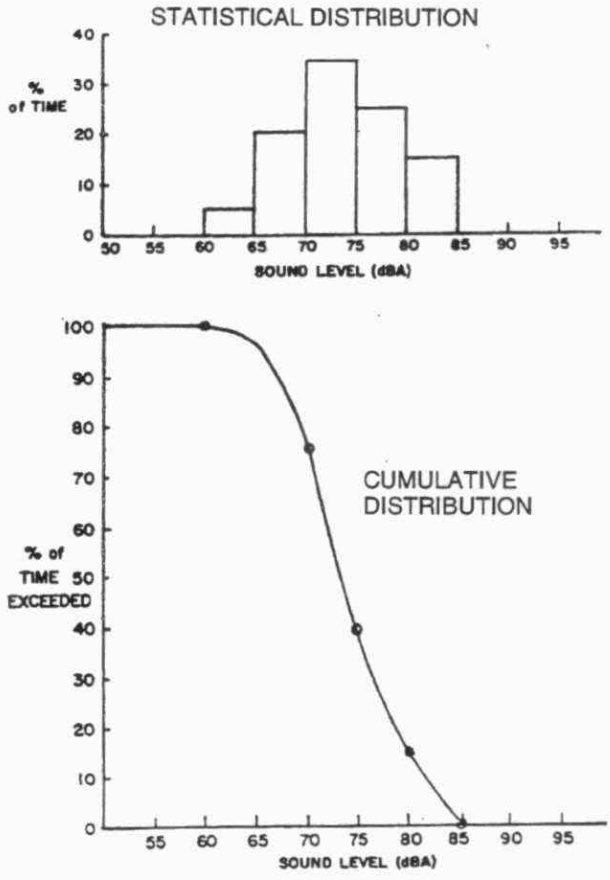


**Figure 3.3 Generation of cumulative distribution plot from statistical distribution plot**

**$L_N$ is the level exceeded for N% of the time. Common $L_N$ values used are as follows:**

$L_{100}$: the level exceeded for 100% of the time or the lowest noise level.

$L_{90}$: the level exceeded for 90% of the time or an indicator of the "ambient" noise level.

$L_{50}$: the level exceeded for 50% of the time or the "medium" noise level.

$L_{10}$: the level exceeded for 10% of the time, measures the "average level of intrusive" noises.

$L_0$: the level exceeded for 0% of the time or the "highest" noise level (also known as $L_{max}$).

By convention $L_{90}$ , $L_{50}$ , and $L_{10}$ are used in common practice to represent approximate measures of background, median and intrusive noise levels respectively. The above statistical values are called percentile levels and they form the basis of many environmental noise rating methods.

## 4.1 PERCENTILE LEVELS FROM CUMULATIVE DISTRIBUTION GRAPH

The percentile levels can be obtained from the cumulative distribution plot. Specific values of six most common descriptors taken from the graph in Figure 3.3 are:

| $L_N$ | SOUND LEVEL dBA |
|---|---|
| $L_{100}$ | 60 |
| $L_{90}$ | 67 |
| $L_{50}$ | 74 |
| $L_{10}$ | 81 |
| $L_1$ | 84 |
| $L_0$ | 85 |

## 5. CONCEPT OF THE ENERGY EQUIVALENT CONTINUOUS LEVEL

The **energy** of a given sound depends not only on its **level**, but its **duration**. Exposure to a loud sound for four hours is much more harmful than a one hour exposure to the same sound. To assess the potential damage of a particular sound **both the sound level and duration of exposure must be measured and combined** to provide a determination of the energy received.

This is easy for constant sounds but if the sound level varies then it must be repeatedly sampled over a well defined sampling period. From this data it is then possible to calculate a single value known as the **equivalent continuous sound level** or $L_{eq}$. The $L_{eq}$ has the same energy content as the varying sounds it represents. In addition to assessing noise-annoyance, the $L_{eq}$ is used to determine the hearing damage potential of a sound.

If the sound level were to vary in a stepwise manner then it would be possible to determine the $L_{eq}$ using a sound level meter and a stopwatch. However if the sound level varies in an unpredictable fashion then it is extremely difficult to evaluate the $L_{eq}$ from manual calculations. In such cases, **INTEGRATING SOUND LEVEL METRES** are used. These instruments automatically calculate the $L_{eq}$ of the sound being measured. $L_{eq}$ measurements can be performed over any suitable period of time.

## 6. TRADE-OFF RELATIONSHIP OF TIME VERSUS SOUND LEVEL

$L_{eq}$ measurement is always performed for a particular time duration. It is necessary to state the time period for the measurement along with the Leq. **If there are two noise sources which are "on" for different**

**time durations, two sources cannot be directly compared by their respective $L_{eq}$ values**. One of the $L_{eq}$ values must first be **corrected** to the same time duration as the other source to allow direct comparison of levels.

The correction factor for $L_{eq}$ values over durations $T_1$ and $T_2$ is:

$$L_{eq2} = L_{eq1} - 10 \log \left[ \frac{T_2}{T_1} \right] \quad dBA$$

This equation shows that a $L_{eq}$ value for a certain time duration will always be decreased when time is lengthened.

The correction must always be used with care. Before it is used, it is necessary to understand the correct method of extending the result of an $L_{eq}$ measurement to a longer duration. Two situations exist:

A short duration sample of the noise produced by a source likely represents its $L_{eq}$ value for as long as the source is "on".

For times longer than for which the machine is "on", that is time which includes periods when the machine is "off", then the trade-off relationship must be used. The time during which the source is "off" will reduce the resultant $L_{eq}$.

## 6.1 EXAMPLE: $L_{EQ}$ VALUES FOR DIFFERENT TIME DURATION

The transformation of $L_{eq}$ for different durations can be illustrated through the following example:

A representative sample of noise was taken for 5 minutes, and the corresponding $L_{eq}$ value of 69 dBA determined. By observation it was found that the source in question was "on" for a total of six hours between 07:00 and 19:00. Calculate the $L_{eq}$ for the day time period (07:00 to 19:00 hours).

$L_{eq}$ for 5 minutes = 69 dBA
$L_{eq}$ for 6 hours = 69 dBA
(machine is "on" for 6 hours)

The $L_{eq}$ for 12 hours (07:00 to 19:00) is required. T1 = 6 hours, T2 = 12 hours.

$L_{eq}$ = 69 - 10 log (12/6)
= 69 - 10 log 2

= 69 - 10 x 0.3
= 69 - 3
= 66 dBA for 12 hours

It should be noted that **if the duration is doubled then 3 dBA must be subtracted** from the measured $L_{eq}$ to give the measured $L_{eq}$ value for the longer time duration. Also note that $L_{eq}$ values for 5 minutes and 6 hours are the same since the 5 minute sample was a representative sample of the noise.

## 7. TIME DURATION IN NOISE ANALYSIS

When taking noise measurements, it is very important to obtain a representative sample. Consider the situation of an industry producing fairly continuous mid-level noise and occasionally performing a venting operation which produces a higher level for a short period of time. In this case, a time period must be used which contains both noise situations, and further, does not place unequal weight on either situation. To ensure that a representative sample has, in fact, been taken, a considerable time period may have to be analysed. In some cases up to several hours or the entire day, evening or night period are monitored on the site and the results analysed.

### 7.1 MINISTRY GUIDELINES

#### 7.1.1 Approval and Abatement

The Ministry uses one hour and the hourly $L_{eq}$ (and $L_{90}$) as the representative time period and descriptors in the area of approval of new and investigation of existing stationary noise sources.

#### 7.1.2 Land Use Planning

For most land use applications, dealing with the noise impact of transportation sources on proposed sensitive land uses, the Ministry uses day-time and night-time as the representative time periods. The daytime is the 16 hour period from 07:00 hours to 23:00 hours. The night-time is the eight-hour period from 23:00 hours to 07:00 hours. The $L_{eq}$ is required for the 16-hour and 8-hour periods.

The Ministry uses the entire 24-hour period for the assessment of freeways and aircraft noise, and a one hour period for noise from stationary sources.

## TOPIC 4. TRANSPORTATION NOISE

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Explain why prediction models are used for transportation models.
2. Describe the variation that can be expected in measurements of $L_{eq}$ from transportation.
3. List the factors which must be accounted for to use ORNAMENT.
4. Use the ORNAMENT and STEAM prediction models.
5. Describe what NEF contours are and when they are used.
6. Give the conversion between $L_{eq}$ and NEF values in decibels.

## TRANSPORTATION NOISE

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# TRANSPORTATION NOISE

## 1. INTRODUCTION

The impact of transportation noise is an important factor to be considered when planning sensitive land uses. This Chapter describes the noise produced by the three transportation sources under consideration: road traffic, railway and aircraft.

The noise impact of transportation sources is typically established through the use of prediction methods. In case of the road and rail sources, the Ministry has established specific prediction methods, namely ORNAMENT and STEAM, which are described in this Chapter. For aircraft noise, the noise impact assessment is based on the Noise Exposure Forecast (NEF) contours, which are developed by Transport Canada. Prediction methods ensure consistency in the noise impact assessments prepared for different land use developments.

The Noise Assessment group of the MOEE has prepared a computerized version of the ORNAMENT and STEAM prediction methods. The program, STAMSON, has been written for the IBM personal computers or compatibles. Copies of the computer program may be obtained from the Air and Noise Section, Approvals Branch, Ministry of the Environment.

## 2. NOISE PREDICTION METHODS

Noise prediction methods are tools used to determine the noise level based on traffic parameters. There are several reasons for the use of prediction methods in noise impact assessment.

The prediction method provides an indication of the noise levels on a particular site when the constraints of time, budget, distant locations, unfavourable weather conditions and availability of instrumentation do not permit on-site measurements. The use of prediction methods also allows for an evaluation of the effects of operational changes in the transportation facilities; for example, the effect of a future increase in the volume of traffic on a particular road can easily be calculated.

Through the use of a prediction, the effectiveness of some noise control measures can be easily evaluated, particularly the effect of increasing the distance between the noise source and the receiver. Finally, prediction methods are the only available tools to evaluate the noise levels when the noise source is still in the planning stage.

The application of road, rail and aircraft noise evaluation method results in the calculation of "free-field" sound levels unaffected by the proposed structure. No requirement for an adjustment due to reflections from the building facade is necessary because the noise criteria also represent the "free-field" sound levels.

## 3. ROAD TRAFFIC NOISE

### 3.1 MECHANISMS OF ROAD VEHICLE NOISE

The noise emitted by a vehicle is caused by the engine, tires and, to a small degree, air turbulence. At low speeds, the engine is the main source of noise; tires and road interaction contribute to noise at high speeds.

The noise due to the engine is produced by radiation of vibrating surfaces and by various individual sources such as exhaust, inlet manifold, transmission and cooling fan. Without any silencing, exhaust and intake are the predominant sources of noise. A silencer provides the most significant reduction of the exhaust noise, and slightly lower reduction to the intake noise. Air intakes of combustion engines are rarely silenced.

At high speeds exceeding 70 km/h, tire noise typically dominates. The tread design, tread wear, tire vibration and the road texture and condition are the major factors in the generation of tire noise. Air being pumped in and out of the tread interstices as the tire segment comes into contact with the road is typically the main contributor.

### 3.2 ROAD TRAFFIC NOISE PREDICTION METHOD - ORNAMENT

The Ministry's recommended prediction method is the Ontario Road Noise Analysis Method for Environment and Transportation, ORNAMENT , published in October 1989. The publication presents a procedure required by this Ministry for the prediction of the energy equivalent sound level, Leq, due to road traffic. The procedure supersedes all other previously used prediction methods. ORNAMENT is also acceptable to the Ministry of Transportation.

ORNAMENT is a simplified version of a method developed and published in 1978 by the United States Federal Highway Administration. As the details of the method are included in the ORNAMENT technical document, only a brief summary is presented in this Section.

The application of ORNAMENT is limited to free flowing vehicular traffic; the method does not apply to stationary vehicles.

### 3.2.1 Elements of the Prediction Model

The noise level produced by road traffic can be viewed as the noise from a set of moving point sources which represent cars, vans, trucks, etc. moving along the roadway. At any instant in time, the vehicular traffic along the roadway consists of a line of point sources. An analysis of these individual sources indicates that a line source model may be used to represent the series of point sources.

The line source model is the basis for many traffic noise prediction methods. Each of the methods approximates the actual noise level but differs from the other in the way the vehicles are classified, in the average noise emission levels for each type of vehicle or the assumptions contained in the adjustments made to the basic predicted level to arrive at the resultant noise level.

In ORNAMENT, the vehicles are divided into three categories: cars, medium trucks and heavy trucks. It is assumed that the vehicles are travelling at the posted speed along the roadway and are spaced equidistant from each other. The reference energy mean sound emission levels for each vehicle category are shown in Figure 4.1 as a function of speed.

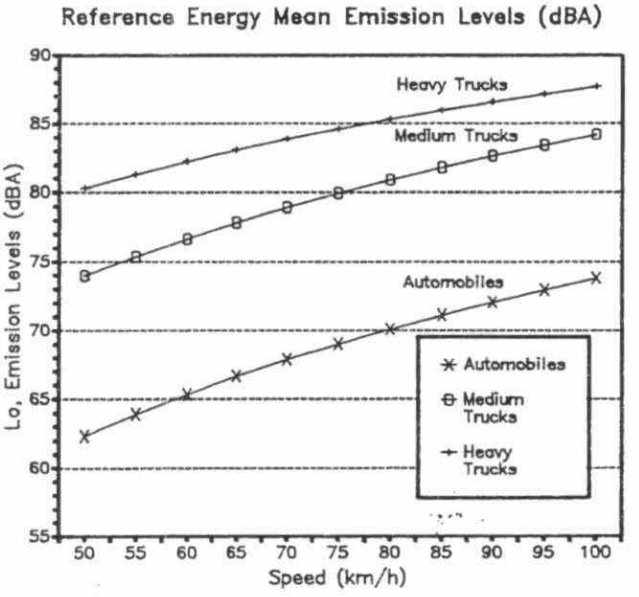



**Figure 4.1 Reference Energy Mean Emission Sound Level of Cars and Trucks; @ 15 m from Roadway Centre-line**

The reference sound level at a distance of 15 m from the centre-line of the road can be determined from Figure 4.1. The reference sound level is then adjusted for total volume, distance, roadway gradient, roadway segment, pavement surface and for shielding by obstacles such as berms, barriers, dense woods and rows of houses.

The details of the adjustments are presented in ORNAMENT. The distance adjustment includes geometric spreading effect as well as the effect due to ground absorption.

### 3.2.2 Road Segments

The prediction method is based on an assumption that, in acoustical terms, a roadway may be represented by a series of straight line sections (segments). An infinitely long and straight roadway would be represented by one segment, defined by angles -90° and 90°. In the case of two infinite roadways affecting the noise level at the receiver, two segments each extending from -90° to 90° would be defined.

A road segment is defined by the following properties:

(i) the width must not be more than four road lanes;

ii) parameters defining the Leq must be the same within the segment; these include road alignment, road gradient, pavement surface, ground surface and shielding.

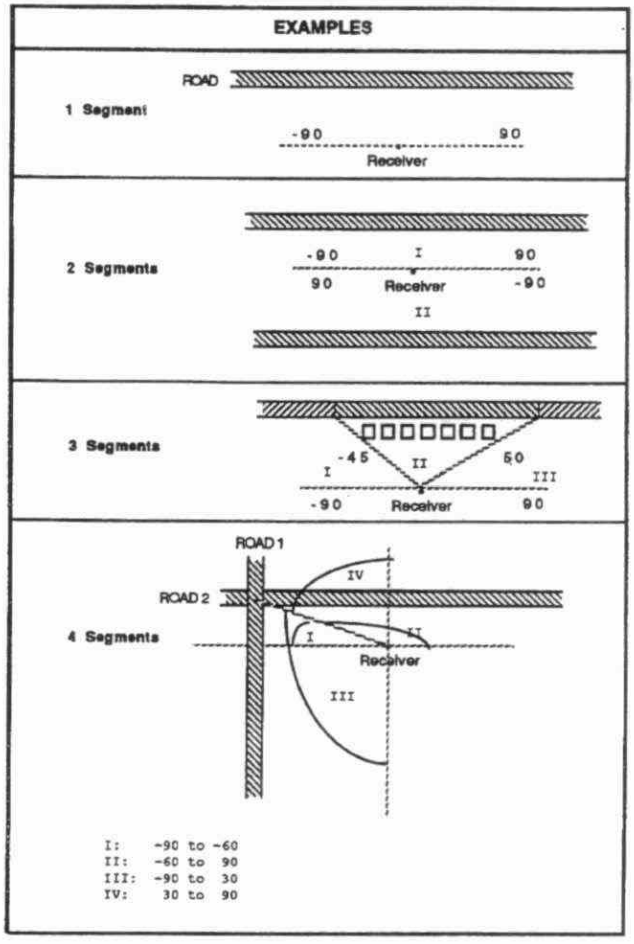



**Figure 4.2 Road Segment Definitions**

For example, for an infinite roadway and a finite noise barrier, the configuration would be presented by three segments: two on either side of the barrier and one for the barrier itself. The segment angles would be given by the angles subtended at the receiver by the barrier.

Figure 4.2 provides the definitions of the segment angles with some examples of various configurations.

### 3.2.3 Effect of Traffic Parameters on Noise Levels

**Traffic Volume**

The doubling of the traffic volume while keeping the other variables constant results in a 3 dB increase in the sound level.

**Traffic Flow Speed**

Changing the traffic flow speed has a slightly different effect on the sound levels for each classification of vehicles and is dependent on the overall composition of the three classes of vehicles. Sound levels corresponding to the range of 50 km/h to 100 km/h increase by 1 dB to 3 dB for every 10 km/h speed increment.

**Distance**

For reflective ground surfaces such as pavement, ice, concrete, water or hard packed earth, the attenuation rate is 3 dB per doubling of distance. For soft, non-reflective surfaces such as ground covered with grass or other forms of vegetation, the attenuation rate is as high as 5.0 dB per doubling of distance, depending on the 'total effective height'. The total effective height is given by the combination of the source height, receiver height and the height of intervening obstacles such as barriers. The attenuation rate decreases with increasing total effective heights, approaching that of the reflective surfaces, i.e. 3 dB per doubling of distance.

## 4. RAIL TRAFFIC NOISE

### 4.1 MECHANISMS OF RAIL TRAFFIC NOISE

The sources of noise from railway rolling stock may be divided into three main categories: the locomotive--engine noise, the movement of the wheels over the tracks, and the audible warning whistle device.

For diesel powered trains, a large portion of the noise is associated with the locomotive itself. As in the case of road vehicles, there are several identifiable noise sources associated with diesel engines but the dominant source is the exhaust stack. The exhaust gases are vented to the atmosphere through the stack outlet which is typically 4.5 m to 5 m above the track level.

Noise due to the wheel-rail interaction is produced by wheels passing over rail imperfections and, when present, over rail joints; continuously welded rails result in significantly lower wheel-rail noise levels. Other potential noise sources are vibration or "ringing" of the steel wheels and the presence of wheel "flats".

### 4.2 RAIL TRAFFIC NOISE PREDICTION METHOD - STEAM

This Ministry's method for the prediction of railway transportation noise is the Sound from Trains Environmental Analysis Method (STEAM). The publication presents a procedure required by this Ministry for the prediction of the energy equivalent sound level, $L_{eq}$, due to train pass-bys. The procedure supersedes all other previously used prediction methods.

The application of STEAM is limited to rolling rail traffic; the method does not apply to railway yards. Other limitations are specified in STEAM publication.

### 4.2.1 Elements of the Prediction Model

The prediction method is based on a model contained in the CMHC publication "Road and Rail Noise: Effects on Housing". This model was developed from empirical expressions established by this Ministry in the mid-1970s. The details of this prediction method are given in the STEAM technical document and only a brief summary will be presented in this Section.

The rail traffic noise source can be modelled as a line source and is similar to the road traffic noise model described in Section 3. The model assumes that the noise level at the receptor is produced by: locomotive engine and exhaust, wheel-rail interaction and whistle.

The model is based on the determination of a reference sound level and a series of adjustments accounting for distance, shielding, time period, and finite track segment. The adjustments to the reference sound level for shielding, distance and track segment are identical to those contained in ORNAMENT, described in Section 3. The definition of railway track segments is also the same as that for the road traffic method, and the description contained in Section 3.2.2 applies with the exception that road segment is replaced by track segment.

## 5. AIRCRAFT AND AIRPORT NOISE

### 5.1 MECHANISMS OF AIRCRAFT NOISE

The noise produced by flying aircraft is unique because the acoustic power generated by a jet aircraft is typically far greater than other conventional noise sources, and the propagation of aircraft noise is virtually unobstructed by intervening structures. The noise is caused principally by the jet exhaust, engine and propellers. The sound power generated increases very rapidly with increasing exhaust jet velocity. Therefore, the turbojet engines of the older aircraft having high velocity exhausts produce high noise levels. The turbofan engines which have replaced the turbojet engines in newer types of commercial aircraft produce significantly lower sound levels.

### 5.2 EVALUATION PROCEDURE

The procedure for airport noise assessment is based on the Noise Exposure Forecast (NEF) and Noise Exposure Projection (NEP) system. All land use proposals near airports must conform to the airport noise

policy of the Ministry of Municipal Affairs and Housing, which is based on the NEF contours and which is designed to protect the land uses as well as the airports.

The calculation of NEF contours requires information about the types of aircraft using the airport and the noise they generate, the number of take-offs and landings on each runway and when the takeoffs and landings occur.

A summation is made of the noise from all aircraft types on all runways in calculating NEF values, taking into account the subjectively annoying effects of aircraft noise including pure tones and duration. The system is used primarily to develop noise contours for areas around airports and it can be used to provide a noise exposure value for one particular location. Figure 4.3 illustrates an NEF contour map for an Ontario airport of medium size. It is important to note that NEF values increase or decrease in a logarithmic manner. The values are specified in terms of simple indices.

The accuracy of the NEF contours will typically be highest near the runways, and will gradually decrease with increasing distance from the runways. NEF contours are based on the average operation over a year. The following approximate conversion holds for NEF and $Leq_{24}$:

$$Leq_{24} = NEF + 31, \text{ dBA}$$

**Sociological surveys have indicated that adverse community reaction may start at about 25 NEF. Above 30 NEF, complaints become increasingly vigorous and may be expected to take the form of concerted group action.**

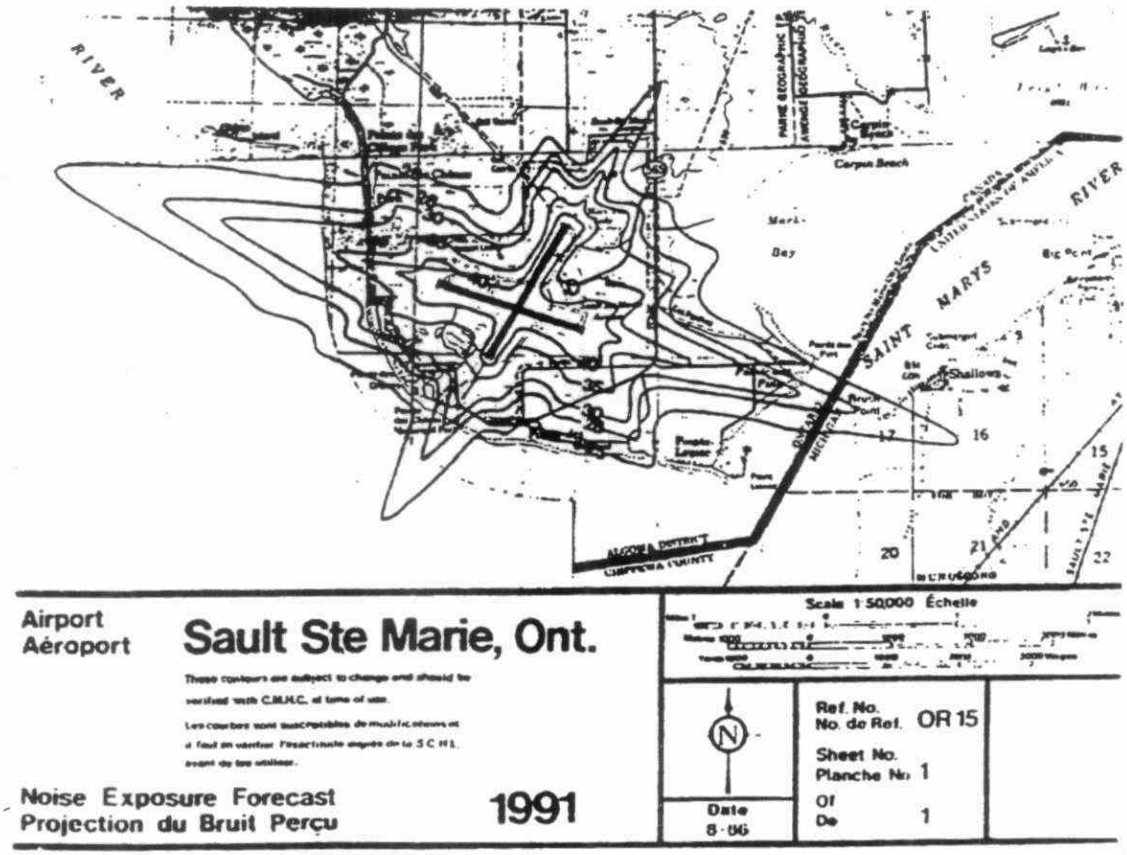



**Figure 4.3 NEF contour map around an Ontario Airport**

Transport Canada has produced Noise Exposure Forecast contour maps for major airports in Canada. These maps are based upon the most up-to-date information available, and where possible, on expected future conditions. They will be revised as airport conditions change. Figure 4.4 provides a list of the NEF/NEP contour maps currently in use in Ontario.

Specific NEF/NEP contour maps may not be available for certain airports. Alternate methods are to be used to evaluate the impact. Transport Canada has prepared general aviation contours for civil airports. These contours are to be used in place of NEF/NEP contour maps.

| AIRPORT | LATEST REVISION | PROJECTION DATE |
|---|---|---|
| | **NEF MAPS** | |
| Brantford | Aug. 1977 | 1991 |
| Buttonville | Mar. 1986 | 1991 |
| Carp | Sep. 1987 | 1992 |
| Hamilton | July 1981 | 1988 |
| Kingston | June 1988 | 1992 |
| London | May 1987 | 1991 |
| North Bay | Dec. 1980 | 1985 |
| Ottawa * | May 1990 | 1994 |
| Pembroke | Dec. 1985 | 1991 |
| Pickering ** | May 1987 | |
| Sarnia | Aug. 1978 | 1986 |
| Sault Ste. Marie | Aug. 1986 | 1991 |
| Sioux Lookout | Mar. 1986 | 1994 |
| Sudbury | June 1973 | 1976 |
| Thunder Bay | Nov. 1984 | 1989 |
| Toronto (Pearson) * | Nov. 1994 | 2000 |
| Toronto Island | Apr. 1978 | 1990 |
| C.F.B. Trenton | Nov. 1985 | 1990 |
| Waterloo-Guelph | Apr. 1977 | 1985 |
| Wiarton | Feb. 1979 | General Aviation |
| Windsor | Feb. 1979 | 1985 |
| | **NEP MAPS** | |
| Markham | Dec. 1982 | 1988 |
| Oshawa | Dec. 1982 | 1991 |
| Ottawa * | Nov. 1984 | 2000 |
| Toronto (Pearson) * | May 1984 | 1996 |

* Land use developments must comply with both the NEF and the NEP contours.

** The Pickering contour is a composite representation of several scenarios.

**Figure 4.4 Currently Available NEF and NEP Contour Maps.**

The Department of National Defence considers the general aviation NEF contours to underrate the noise around military airports. For these cases, the aircraft noise assessment is based on the length of the runway; residential development should not be considered within the shaded areas shown in Figure 4.5.

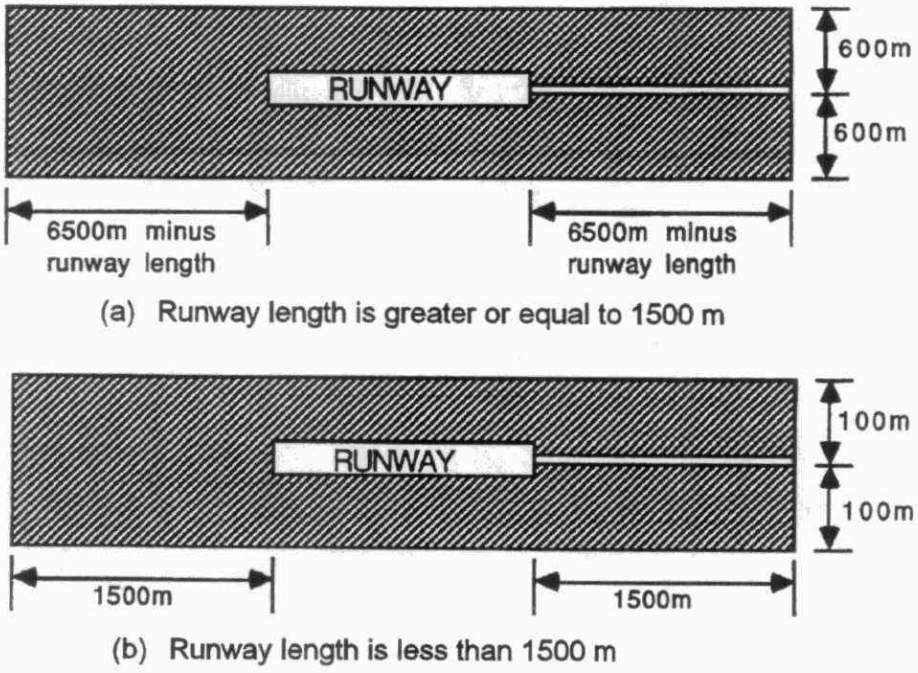



**Figure 4.5 Noise Zone at Military Airports where NEF Contours are Unavailable**

## 5.3 EVALUATION OF INTERMEDIATE NEF/NEP CONTOURS

Transport Canada and the Department of National Defence provide NEF/NEP contours spaced at different intervals. For example, the contours developed by Transport Canada are spaced at intervals of five points from 25 to 40. The intermediate contours are not evenly spaced because of the logarithmic nature of the contour calculation.

The location of the missing contours can be determined using the following method. Determine the distance between two adjacent contours, for example, between 25 and 30 NEF and let this distance be S. The NEF 29 contour is found at a distance of 0.15 S from the NEF 30 contour, NEF 28 is at 0.33 S, NEF 27 is at 0.52 S and NEF 26 is at 0.74 S from the NEF 30 contour. The same method can be applied to any set of adjacent contours of the NEF map.

The following text forms part of an MOEE publication

# ORNAMENT

## Ontario Road Noise Analysis for Method for Environment and Transportation

ISBN 0-7729-6376

### ROAD TRAFFIC VOLUME CALCULATION

The following information should be obtained when assessing the road traffic noise impact on planned sensitive land uses:

1. The Average Annual Daily Traffic Volume (AADT) and, when available, the Summer Annual Daily Traffic Volume (SADT); the higher of the two should be used;

2. Composition of traffic in terms of the percentages of automobiles, medium trucks and heavy trucks;

3. Posted speed limit (km/h).

When assessing the noise impact, traffic volumes should be based on future traffic projections of at least 10 years after the completion of the planned project or the ultimate capacity indicated by the road authority.

Although the SADT and AADT volumes are 24 hour traffic volumes, the prediction method is based on the 1 hour equivalent sound level, $L_{eq}$. Furthermore, except for freeways for which the assessment is performed based on the 24 hour traffic volume, the assessment is performed for the 16 hour day-time (07:00 to 23:00) and the 8 hour night-time periods (23:00 to 07:00) separately.

The following expression may be used to convert from the 24 hour road traffic volume information to the 1 hour volume for the 8, 16 or 24 hour periods:

$$\text{Volume (T)} = \frac{\text{24 hour Volume (SADT or AADT)} \times P_T/100}{T}$$

where T is the time period in hours, i.e. 8, 16 or 24 hrs,
and $P_T$ is the percentage of the 24 hour volume in the period T

The recommended day-night traffic volume ratios are:

90% - 10%, for regional roads,
85% - 15%, for provincial roads, and
67% - 33%, i.e. same volume day or night, for freeways.

So, for example, for a regional road for which the day/night traffic volume ratio is 90/10 %, the 1 hour day-time volume is:

$$\text{Volume (1)} = \frac{\text{24 hour Volume (SADT or AADT)} \times 0.9}{16}$$

and the 1 hour night-time volume is:

$$\text{Volume (1)} = \frac{\text{24 hour Volume (SADT or AADT)} \times 0.1}{8}$$

For a freeway, the 1 hour volume (day or night) is:

$$\text{Volume (1)} = \frac{\text{24 hour Volume (SADT or AADT)}}{24}$$

The following text forms part of an MOEE publication

# S T E A M

# Sound from Trains Environmental Analysis Method

ISBN-7729-6376-2

## RAIL TRAFFIC INFORMATION AND DAY/NIGHT CONVERSION

The following information is required for the assessment of rail traffic noise impact on planned sensitive land uses:

1. Train types within day-time and night-time periods. The types are typically identified as passenger trains, freight trains, etc.

2. Number of trains corresponding to each train type within both day-time and night-time periods. Number of locomotives per train, number of cars per train and train speed.

**The rail traffic information used in the prediction should be based on future traffic projections of at least 10 years. The standard increase of rail traffic is 2.5 % per annum.**

When day-time and night-time sound level calculation is performed using known train traffic volumes in the 16-hour and 8-hour periods but utilizing the 24-hour sound level data in Tables 1, 2 and 3, conversion has to be performed. This conversion may be done either by correcting the 24-hour traffic volume, at the beginning of the calculation, or by adjusting the calculated sound levels, at the end of the calculation. Both methods produce the same results:

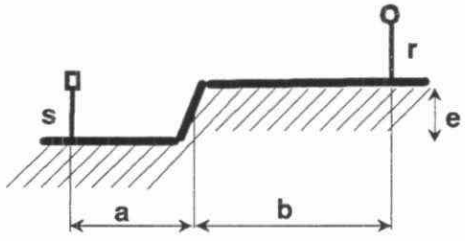
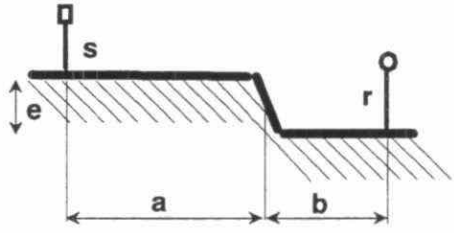
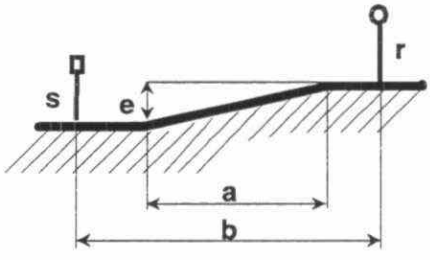
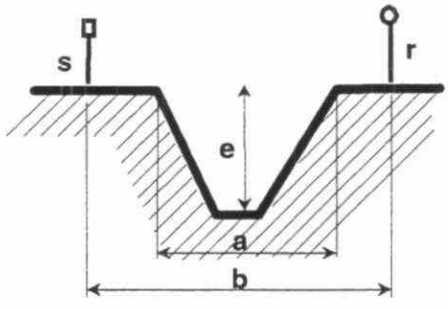
1. The first option is to begin the calculation by multiplying the actual 24-hour number of trains by a factor of 1.5, for calculation in the 16-hour period, and subsequently by a factor of 3, for calculation in the 8-hour period 3, and proceed with the 24-hour calculation.

   Example: 10 trains day-time, 6 trains night-time
   The calculation should done separately using 15 day-time trains and 18 night-time trains.

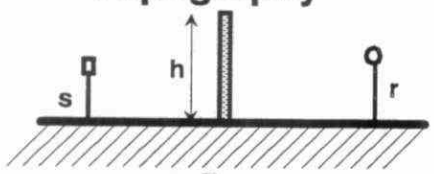
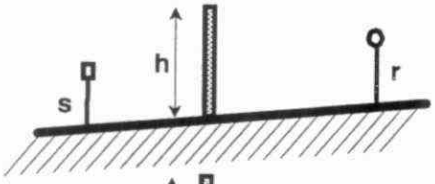
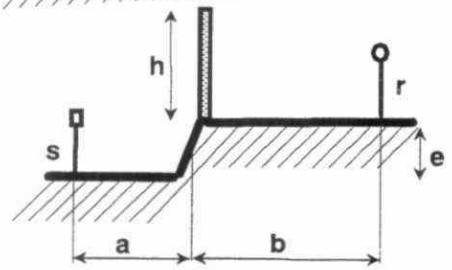
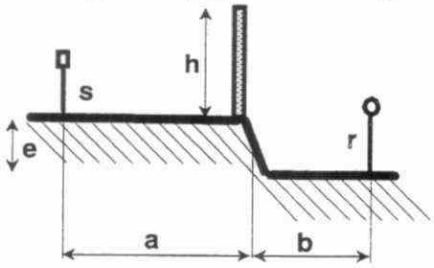
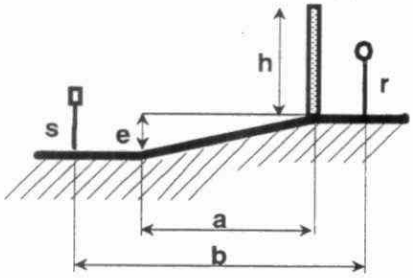
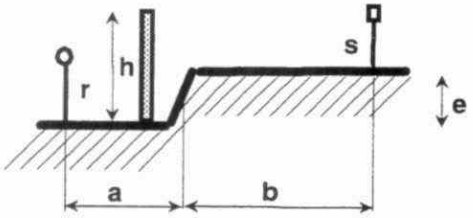
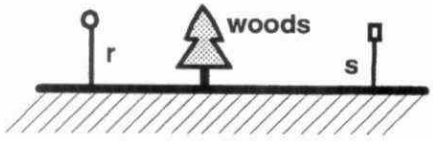
2. The second option is to calculate the noise levels in the 8-hour and 16-hour periods based on the numbers of trains within these two periods, but using the 24-hour sound level data. Under these circumstances, the calculated sound levels have to be adjusted by:

| | | |
|---|---|---|
| Correction | = | 10 log (24/16) = +1.8 dBA, day-time |
| | = | 10 log (24/8) = +4.8 dBA, night-time. |

# TOTAL EFFECTIVE HEIGHT DEFINITIONS

| | Topography | Definition |
|---|---|---|
| 1. | | s + r |
| 2. | | As 1, s + r |
| 3a. |  | s + r + e, if b < a/2<br>s + r, else |
| 3b. |  | s + r + e, if a < b/2<br>s + r, else |
| 4. |  | As 2, if a > b/2<br>As 3, if a < b/2 |
| 5. |  | As 1, if a < b/2<br>s + r + 2e, if a > b/2 |

**Definitions of the Total Effective Height for Varying Topographies**

| Topography | | Definition |
|---|---|---|
| 6. |  | s + r + 2h |
| 7. |  | As 6, s + r + 2h |
| 8a. |  | s + r + e + 2h, if b < a/2<br>s + r + 2h, else |
| 8b. |  | s + r + e + 2h, if a < b/2<br>s + r + 2h, else |
| 9. |  | As 7, if a > b/2<br>As 8, if a < b/2 |
| 10. |  | As 3, if h < e<br>s + r + e + 2(h - e), if h > e |
| 11. |  | s + r + 2w, w = 5 m |

**Definitions of the Total Effective Height for Varying Topographies (cont.)**

## TOPIC 5. NOISE IMPACT ASSESSMENT

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Understand the need for outdoor and indoor sound level criteria.
2. Know the appropriate sound level criteria.
3. Know the locations of noise impact assessment.
4. Know the minimum noise control measures and when they should be used.
5. Be aware of implementation guidelines for land use affected by: airports, roads, railways, stationary sources, and multiple sources.

## NOISE IMPACT ASSESSMENT

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# NOISE IMPACT ASSESSMENT

## 1. BACKGROUND TO NOISE CRITERIA

Noise can have adverse effects on human beings through interference with speech, activity, comfort, sleep, etc. Noise criteria are required for two basic reasons: first to determine whether a particular noise environment can potentially have adverse effects on humans and, second, as an objective for the design of noise control measures.

The stages in establishing sound level criteria follow from these two requirements. Firstly, the various human activities in their appropriate locales (residence, motel, office, etc.) are identified; secondly, the time and place of such activities are determined; thirdly, the noise level descriptors, such as the $L_{eq}$, most applicable to the particular activity is determined; and, finally, a value is assigned to the descriptor(s) to establish the dividing line between acceptable and unacceptable noise environments and to provide a target for noise abatement.

Certain other factors need consideration: annoyance is one example of these. Noise could well be annoying, irritating or unbearable, in spite of the fact the noise does not disturb any particular activity. Hearing loss may also be a consideration in the case of a long-term exposure to high intensity noise. What has been assumed to be an age-induced hearing loss could be a hearing loss due to continuous exposure to high noise levels.

The choice of noise descriptors for rating noises is an area of continuing research. Many descriptors exist and it is difficult to select a universal descriptor. Sociological surveys, jury testing and other research methods have, however, provided valuable information on the relative merits of descriptors, so that only a few descriptors need to be used to cover most situations.

The most common sound level descriptor used by the Ministry of Environment and Energy is the energy equivalent continuous sound level ($L_{eq}$), also known as equivalent sound level.

## 2. SOUND LEVEL CRITERIA

The MOE has established sound level criteria for each category of noise sources. The MOE Guideline LU-131, Noise Assessment Criteria in Land Use Planning, presented in an Appendix, contains a full description of the applicable criteria.

## 2.1 ROAD AND RAIL TRAFFIC

Table 5.1 gives the sound level criterion in terms of the equivalent sound level ($L_{eq}$) in the selected Outdoor Living Area. The criterion applies to the day-time period from 07:00 to 23:00.

| Time Period | $L_{eq}$ (dBA) |
|---|---|
| 07:00 - 23:00 | 55 |

**Table 5.1 Sound Level Criterion for Outdoor Living Areas, Road and Rail**

Table 5.2 gives the equivalent sound level ($L_{eq}$) criteria and the applicable time periods for the indicated types of indoor space. The specified sound level limits are minimum requirements and apply to the indicated indoor spaces with the windows and doors closed. No noise control measures are required if the sound level estimated in the plane of a window or a door is 55 dBA or less during the day-time and 50 dBA or less during the night-time.

| Type of Space | $L_{eq}$ (dBA) | |
|---|---|---|
| | Road | Rail |
| Living/dining areas of residences, hospitals, schools, nursing/retirement homes, day-care centres, etc. (Time period 07:00 - 23:00) | 45 | 40 |
| Sleeping quarters (Time period 23:00 - 07:00) | 40 | 35 |

**Table 5.2 Indoor Sound Level Criteria, Road and Rail**

## 2.2 AIR TRAFFIC

Table 5.3 gives the aircraft noise criterion in terms of an NEF/NEP value in any outdoor area, including the Outdoor Living Area. The criterion applies to the 24-hour period. The distance separation from the airport and, consequently, the location of the noise sensitive land use with respect to the NEF/NEP contours, is the only measure that controls the outdoor noise impact.

| Time Period | NEF/NEP |
|---|---|
| 24 hours | 30 * |

* Certain conditions apply above NEF/NEP value of 25. The criterion may not apply to redevelopment and infilling. See LU-131.

**Table 5.3 Outdoor Aircraft Noise Criteria**

Table 5.4 gives the indoor criteria in terms of NEF/NEP values for the indicated type of indoor space. These criteria apply to the entire 24-hour period. The specified criteria are minimum requirements and apply to the indicated indoor spaces with the windows and doors closed. No noise control measures are required if the outdoor NEF/NEP value is less than 25.

| Type of Space | Indoor NEF/NEP |
|---|---|
| Living/dining areas of residences, hospitals, schools, nursing/retirement homes, day-care centres, etc. | 5 |
| Sleeping quarters | 0 |

* The Indoor NEF/NEP values listed in Table 5.4 are not obtained from NEF/NEP contour maps. The values are representative of the indoor sound levels and are used as assessment criteria for the evaluation of acoustical insulation requirements.

**Table 5.4 Indoor Aircraft Noise Criteria * (Applicable over 24-hour period)**

## 2.3 STATIONARY SOURCES

In comparison to noise from transportation sources, noise from stationary sources such as industrial activities, commercial activities or rail yards, is usually controlled more effectively at the source. Sound level criteria are given in MOE Guideline LU-131, Noise Assessment Criteria in Land Use Planning, presented as an Appendix.

# 3. SUBJECTIVE RATING OF NOISE IMPACTS

The general objective the noise criteria described in the previous section is prevention of adverse effects. This objective implies that, provided these criteria are not exceeded, the majority of people will not be adversely affected; therefore, the subjective rating of the noise impact is "none". However, due to the

variation in human response to noise, compliance with the criteria does not imply an absolute satisfaction for all people. Nevertheless, the following discussion assumes that no excess above the criteria is equivalent to no adverse effect and no subjective noise impact.

In order to gain an appreciation of the reaction of people to noise, it is useful to rate the subjective impact of noise in the context of compliance with the criteria. Such a rating is presented in Table 5.5. The table shows several categories of excess above the noise criteria, the subjective loudness of noise and the extent of the noise impact. However, the rating in the table is a very simplistic because there are several types of criteria depending on the category of noise source and the location of the receptor. In fact, the application of Table 5.5 is limited to the assessment of the outdoor noise impact produced by transportation sources, particularly road and rail sources. Indoor sound levels, for example, should not be interpreted using magnitude grading of the table; indoor sound levels are expected to comply with the indoor criteria. Noise from stationary sources should also not be judged using the rating in the table.

| EXCESS ABOVE SOUND LEVEL CRITERION (dBA) | CHANGE IN SUBJECTIVE LOUDNESS | SUBJECTIVE RATING OF NOISE IMPACT |
|---|---|---|
| No excess | --- | No expected noise impact |
| 1 to 3 inclusive | Generally imperceptible | Insignificant |
| 3 to 5 inclusive | Clearly perceptible | Noticeable |
| 5 to 10 inclusive | Almost twice as loud | Significant |
| 10 and over | More than twice as loud | Very significant |

**Table 5.5 Applying Recommended Sound Level Limits to Outdoor Living Areas (Road and Rail Traffic only)**

The above Table 5.5 indicates that an excess of 1 to 5 dB in Outdoor Living Areas produces an insignificant or noticeable noise impact. Since the rating of impact is only slight, some flexibility has been built into the application of the outdoor sound level criteria. In cases where the impact does not exceed 5 dB, the noise levels in the Outdoor Living Areas can be reduced not only through physical control measures but alternatively by notifying prospective purchasers and tenants of the potential noise problem by the use of suitable warning clauses.

A warning clause is a formal notification of a condition affecting the use of land due to environmental concerns. The main intent of the warning clause is to inform the purchaser or the tenant that noise may or will interfere with his or her daily activities. Appropriate wording for warning clauses is given in MOE Guideline Noise Assessment Criteria in Land Use Planning: Requirements, Procedures and

Implementation, presented as an Appendix. The warning clause must appear as a specific section of a registered agreement, such as a Subdivision Agreement, which stipulates that a prospective purchaser or tenant must be advised of the potential noise concern.

When the excess is more than 5 dB, the recommended physical control measures for transportation noise sources must reduce the outdoor sound level as close to the sound level limit as possible. For instance, if the outdoor sound level from road traffic is 63 dBA, the sound attenuation provided by the barrier must be as close to 8 dB as possible and not just 3 dB.

The subjective noise impact rating outlined in this section applies to transportation noise sources which are the most common sources of noise. Although some flexibility has been incorporated into the application of noise criteria for stationary sources, see the annex of LU-131, Noise Assessment Criteria in Land Use Planning, the rating of Table 5.5 and the subsequent conclusions do not apply to stationary noise sources.

## 4. LOCATIONS OF IMPACT ASSESSMENT

The sound level criteria described in the previous sections provide a basis for the design of noise control measures required for the proposed land use. The noise control measures, if needed, are designed to ensure that the criteria are met and to provide a comfortable living environment.

Depending on the type of noise source, noise impact assessment is performed at various locations. These locations are the Outdoor Living Area, various indoor spaces, outdoor Point of Reception and plane of a window.

### 4.1 OUTDOOR LIVING AREA

A simple definition of the Outdoor Living Area is as follows. (For complete definition, please see MOE Publication LU-131, Noise Assessment Criteria in Land Use Planning). The Outdoor Living Area is an area reserved for the passive enjoyment of the outdoors. The Ministry requires the Outdoor Living Area to be not less than 56 $m^2$ (600 $ft^2$) for single family homes; 46 $m^2$ (500 $ft^2$) for each semidetached unit; and 37 $m^2$ (400 $ft^2$) per unit for row housing.

Note: The Ministry accepts an Outdoor Living Area located in the front yard as long as the municipality approves the same.

In order to comply with the Ministry's guidelines, the noise level must be assessed in the Outdoor Living Area, such as a rear yard or a patio, and in indoor living areas, such as bedrooms and living rooms. To

accomplish this, the free-field equivalent sound level must be evaluated at a minimum of two outdoor receiver locations, typically defined as follows:

- 3 m from the building facade and 1.5 m above ground, for the purposes of evaluating the impact in the Outdoor Living Area.

- in the plane of a bedroom window, usually 4.5 m above ground at second storey, for the purposes of evaluating the impacts in bedrooms.

### 4.1.1 Balconies

Balconies are defined as Outdoor Living Areas provided that they are not enclosed and are not part of the floor space, that they have a minimum depth of 4 m, and that no common recreation areas for communal use are provided in the complex.

Mitigation measures are not considered if balconies are not defined as Outdoor Living Areas but a warning clause is required if the noise impact exceeds the Ministry's noise guidelines. Mitigation measures are required if balconies are defined as Outdoor Living Areas. The extent of the control measures depend on the magnitude of noise impact and the feasibility of implementation.

## 4.2 POINT OF RECEPTION

The noise impact produced by stationary sources is assessed at an outdoor Point of Reception in any area amenable for use. The Point of Reception means any point on the premises of a person where sound or vibration originating from other than those premises is received. The noise impact assessment has to be performed at any such point in an area on the property, provided the area can be used.

The assessment would not have to be performed in unusable area, for example a very narrow strip of land at the back/side of a house.

## 4.3 INDOOR LIVING AREA

The indoor impact produced by transportation sources is assessed by calculation (prediction), under the assumption of a spatially unvarying sound level throughout the indoor area. The assessment is performed for two time periods: day-time, 07:00 - 23:00, and night-time, 23:00 - 07:00. The indoor living areas assessed during day-time are the living/dining areas of residences, hospitals, schools, nursing/retirement homes, day-care centres, etc. The indoor living areas assessed during night-time are the sleeping quarters (bedrooms).

Assessment of the indoor noise impact is not required for stationary sources; the appropriate indoor sound level produced by stationary sources is provided through compliance with the plane of the window noise criteria.

### 4.4 WINDOW

For stationary noise sources, the noise impact in the plane of a window is assessed under free field conditions, at a representative point where the window would be located. The assessment is performed for two time periods: day-time, 07:00 - 23:00, and night-time, 23:00 - 07:00. The day-time criteria apply to windows in living/dining areas of residences, hospitals, schools, nursing/retirement homes, day-care centres, etc. The night-time criteria apply to windows in sleeping quarters (bedrooms).

## 5. NOISE CONTROL MEASURES

The term noise control measure refers to action taken to achieve compatibility for the specific land use or activity. The control measure should be permanent in nature and not be readily removable or alterable by the future occupants. Warning clauses that inform prospective occupants of potential noise problems are not classified as noise control measures despite the fact that they often discussed in the context of noise control measures.

The MOE Guideline Noise Assessment Criteria in Land Use Planning: Requirements, Procedures and Implementation outlines the minimum measures that are required to be incorporated into the design of a development or into the design of individual dwellings in order to comply with the Ministry's noise criteria. The criteria are given in LU-131.

Noise control measures usually fall into the following categories:

| | |
|---|---|
| Barriers: | berms, walls, favourable topographical features, other intervening structures; |
| Architectural Design: | room and corridor arrangement, blank walls, placement of windows, balconies, and courtyards, building height; |
| Building Construction: | acoustical treatment of walls, ceilings, selection of acoustical materials and other control devices. Provision for air conditioning; |
| Mitigation at Source: | noise control applied directly to the noise source; |

Site Planning: orientation of buildings and Outdoor Living Areas with respect to noise sources, spatial separation such as the insertion of noise insensitive land uses between source and receiver, appropriate setbacks, and the use of intervening service roads;

Windows/Doors: acoustically designed windows or doors that provide the required noise reduction. In order to allow for the windows and doors to remain closed, air conditioning, i.e. mechanical ventilation and climatic control system, is necessary.

## 6. NOISE IMPACT STUDIES

Feasibility noise studies or detailed noise studies may be needed to support the development proposal. MOE Guideline Noise Assessment Criteria in Land Use Planning: Requirements, Procedures and Implementation contains more detailed information on the conditions under which these studies are generally required.

The objective of the feasibility study is to estimate the feasibility of the proposal in the context of site design and the extent of control measures such as barriers, ventilation requirements and building components. Feasibility studies should be submitted with the initial proposal.

The feasibility study should also assess the site layout including the roadways and orientation of the buildings, as well as allow for consideration of the appropriate zoning including industrial, commercial, high, low and medium density residential use. The study should alert the proponent and the approving agency of potential land use conflicts as well as determine the practicality and economic feasibility of physical noise control measures, in conjunction with the selected site design. Furthermore, the study should provide a clear direction regarding the need for additional studies and the timing associated with the implementation of required control measures.

The purpose of the detailed study is to assess the impact of all noise sources affecting the subject lands and determine the appropriate layout, design and required control measures. The study report should include details of assessment methods, summarize the results and recommend the required outdoor as well as indoor control measures. The requirement for a detailed noise study may be a condition of initial approval of the proposed development; however, detailed studies may be prepared and submitted in place of feasibility studies.

Noise impact studies should be prepared by a qualified individual, preferably a Professional Engineer with experience in environmental acoustics.

## 6.1 LAND USES NEAR AIRPORTS

1. A detailed noise study is required for proposals that are located at or above NEF/NEP 25. The study should be submitted with the initial proposal. It should be noted that certain airport facilities and activities are considered as stationary sources of noise, see MOE Guideline Noise Assessment Criteria in Land Use Planning: Requirements, Procedures and Implementation.

2. The detailed noise study should contain:
   (a) NEF/NEP values for the site;
   (b) ventilation requirements;
   (c) appropriate warning clauses;
   (d) acoustical insulation parameters (AIF or STC) of the exterior building components of various rooms; and
   (e) suitable choices for the exterior building components: walls, windows, doors and ceiling/roof.

3. Implementation of noise control measures should be verified (certified) by a qualified individual, preferably a Professional Engineer with experience in environmental acoustics.

## 6.2 LAND USES NEAR ROADWAYS AND RAILWAYS

### 6.2.1 Conditions for Feasibility Studies

The requirement for feasibility is governed by two alternate conditions. The first is a condition based on the potential excess above the criteria. This is the preferred condition but may be harder to implement. The condition is that:

- The sound levels resulting from surface transportation noise affecting the proposed lands exceed the noise criteria by more than 10 dBA.

Alternatively, the requirement for a feasibility study may be defined in terms of a setback distance from the noise source. These setback requirements are typically easier to implement. The following setback distances are guidelines as they may vary depending on individual site specific conditions, particularly topography, trigger the requirement for a feasibility study:

- The proposed lands are within 100 m from a freeway right-of-way or 50 m from a provincial highway right-of-way;

- The proposed lands are within 100 m from a Principal Main Railway Line right-of-way or 50 m from a Secondary Main Railway Line right-of-way.

Irrespective of the above conditions, it is in the interest of the proponent to perform a feasibility study in the early planning stages.

### 6.2.2 Conditions for Detailed Studies

Similarly to the requirements for feasibility studies, the requirement for detailed studies is governed by two alternate conditions. The first is a condition based on the potential excess above the criteria. This is the preferred condition but may be harder to implement. The condition is that:

- The sound levels resulting from surface transportation noise affecting the proposed lands exceed the noise criteria by more than 5 dBA.

Alternatively, the requirement for a detailed study may be defined in terms of a setback distance from the noise source. These setback requirements are typically easier to implement. The following setback distances are guidelines as they may vary depending on individual site specific conditions, particularly topography, trigger the requirement for a detailed study:

- The proposed lands are within 500 m from a freeway right-of-way, 250 m from a provincial highway, or 100 m from the right-of-ways of other roads;
- The proposed lands are within 500 m from a Principal Main Railway Line, 250 m from a Secondary Main Railway Line, or 100 m from other railway lines.

### 6.2.3 Contents of Studies

1. If a feasibility study is required, it should be submitted with the initial land use proposal.

2. A requirement for a detailed noise study is generally a result of a conditional approval. If the detailed noise study is required, it should be prepared and submitted prior final approval.

3. Road and rail traffic noise assessment should be performed using the MOE prediction methods, namely ORNAMENT and STEAM.
4. The detailed noise study should contain:
   (f) sound levels based on the future increases in traffic volumes (at least ten year forecast) for daytime and nighttime periods;

(g) physical noise control measures such as barriers, distance setback and orientation of the buildings;

(h) ventilation requirements;

(i) appropriate warning clauses;

(j) acoustical insulation parameters (AIF or STC) of the exterior building components of various rooms; and

(k) suitable choices for the exterior building components: walls, windows, doors and ceiling/roof.

5. Implementation of noise control measures should be verified (certified) by a qualified individual, preferably a Professional Engineer with experience in environmental acoustics.

## 6.3 LAND USES NEAR STATIONARY SOURCES (INDUSTRIAL/ COMMERCIAL NOISE SOURCES)

1. Noise feasibility study is required.

2. A detailed noise study is required; it should be prepared by the proponent's consultant. The required information for a stationary source is outlined in the MOE Publication NPC-233, Information to be Submitted for Approval of Stationary Sources of Sound.

3. The noise assessment should be performed using recognized prediction methods.

4. If control measures are required to reduce the noise impact, these measures should be designed in accordance with the following principles:

(a) Noise from stationary sources is generally controllable at lower cost at the source than at the Point of Reception and, consequently, source mitigation is the preferred option;

(b) Cooperation between the developer and the owner of the stationary sources is highly desirable and often essential in order to achieve the required mitigation;

(c) Installation of noise control measures at the source will typically require a Certificate of Approval (Air), as specified in Section 9 of the Environmental Protection Act;

(d) Noise control measures aimed at the indoor environment, such as air conditioning, are usually immaterial because the criteria for stationary source sound levels apply to the plane of windows; the sound levels are estimated in the absence of the building. The use of central air conditioning may be acceptable under special

circumstances, in certain types of developments, when the central air conditioning system forms an essential part of the overall building design - details are described in the annex to LU-131, Noise Assessment Criteria in Land Use Planning;

(e) Assessment of noise impact produced by stationary sources typically involves calculation of sound emissions from the source, transmission and propagation of sound and the effect of intervening obstacles such as barriers. The calculation should account for the frequency characteristics of the noise source.

5. Implementation of noise control measures should be verified (certified) by a qualified individual, preferably a Professional Engineer with experience in environmental acoustics.

NOTE: Closed or sealed (non-operable) windows along with central air conditioning are generally unacceptable controls for noise from stationary sources, see the annex of MOE Guideline LU-131, Noise Assessment Criteria in Land Use Planning, for additional explanation. Noise warning clauses for stationary sources are also generally unacceptable. A warning clause may be used for emergency upsets such as blow-downs of natural gas transmission lines and pumping stations.

## 6.4 LAND USES NEAR MANY SOURCES

A land use development proposal may be impacted by noise produced by more than one source. The evaluation procedure for multiple sources is similar to the methods outlined in Sections 6.1, 6.2 and 6.3. The difference is in the technical assessment procedure and this is described below.

- The sound levels and sound insulation ratings for road and rail traffic are combined as follows:

$$L_{eq}\ (day) = 10 \log \left[ 10^{\frac{L_{eq,road}(day)}{10}} + 10^{\frac{L_{eq,rail}(day)}{10}} \right]$$

$$AIF = 10 \log \left[ 10^{\frac{AIF_{road}}{10}} + 10^{\frac{AIF_{rail}}{10}} \right]$$

$$STC = 10 \log \left[ 10^{\frac{STC_{road}}{10}} + 10^{\frac{STC_{rail}}{10}} \right]$$

- The sound level produced by stationary sources is evaluated in terms of the one hour equivalent sound level $L_{eq}$. For more than one stationary source, the sound levels $L_{eq}$ from the individual sources are combined.

- The outdoor control measures for developments impacted by road and rail traffic noise are designed using the combined sound level; the indoor sound levels and the associated insulation requirements are evaluated using the AIF and STC equations above.

- The indoor sound levels produced by aircraft and the associated insulation requirements, evaluated in terms of AIF and STC, are calculated separately from other noise sources.

- The resultant insulation requirements, evaluated in terms of AIF and STC, are calculated combining the AIF or STC values calculated for road, rail and aircraft sources:

$$AIF = 10 \log \left[ 10^{\frac{AIF_{road}}{10}} + 10^{\frac{AIF_{rail}}{10}} + 10^{\frac{AIF_{air}}{10}} \right]$$

$$STC = 10 \log \left[ 10^{\frac{STC_{road}}{10}} + 10^{\frac{STC_{rail}}{10}} + 10^{\frac{STC_{air}}{10}} \right]$$

- The sound level at an outdoor Point of Reception, produced by all stationary noise sources, is assessed (as if a single source) separately from other noise sources. The required outdoor control measures (barriers and mitigation at source) should ensure compliance with all applicable criteria.

## 7. REPORT FORMAT

The report must contain the required information, organized in a clear and concise manner. Results should be presented in a tabular form, presenting pre- and post-abatement sound levels. The report should include the following sections in the given sequence:

1. Introduction (Background Information)

   Project description, site description, historical information on area, acoustic environment, etc.

2. Description of Sources

   Noise and vibration sources affecting the site. The type of source generally determines the applicable distance. For detailed studies, sources within 500 m of the site should be assessed; however, for large industrial sources, the distance would be 1000 m or more.

3. Impact Assessment

   Applicable criteria and results of impact assessment at the critical locations prior the abatement due to individual as well as combined sources.

4. Mitigation Measures

   Description and assessment of control measures and results of impact assessment at the critical locations following abatement. The control measures have to address the outdoor as well as indoor sound levels.

5. Conclusions and Recommendations

   Summary of impacts, verification of compliance with criteria and summary of control measures.

6. Appendices, etc.

   Details of measurements and calculations, specifications, plans, engineering drawings, etc.

## 8. CHECKLIST FOR NOISE REPORTS

In accordance with the MOE practices, the noise reports should be accompanied by a standard form that summarizes the pertinent information regarding the status and purpose of the project, and the contents of the report. The MOE uses the Checklist for Environmental Noise Impact Reports (attached) that proponents are required to complete.

The Checklist requires proponents to supply the basic information relating to the development application such as the approving authority, the OPA number or other identifier, and pertinent correspondence. The Checklist also requires the proponents to supply site plans, identify significant noise sources within 500 m and show NEF and/or NEP contours of 25 or greater.

## 9. REFERENCES

The following MOE guidelines are pertinent:

1. LU-131, Noise Assessment Criteria in Land Use Planning
2. Noise Assessment Criteria in Land Use Planning: Requirements, Procedures and Implementation

Ontario

Ministry of the Environment | Ministère de l'Environnement

# CHECKLIST FOR ENVIRONMENTAL NOISE IMPACT REPORTS

The objective of this form is to ensure that the minimum MOE requirements for a report addressing the noise impact on a sensitive land-use proposal are satisfied. This form should be completed by the proponent or the acoustical consultant and all items listed on this form should be answered and required documents included with the noise report.

| PROPONENT/DEVELOPER: | DEVELOPMENT IDENTIFICATION: |
|---|---|
| | |

## 1. IDENTIFY THE PURPOSE OF THIS NOISE REPORT - THE REPORT SUPPORTS AN APPLICATION TO:

(a) ☐ amend an Official Plan; OPA No.: _____

(b) ☐ rezone; Rezoning No.: _____

(c) ☐ obtain Draft Approval; Plan No. _____ T _____ or _____ CDM _____

(d) ☐ clear conditions of Draft Approval; Plan No. _____ T _____ or _____ CDM _____

(e) ☐ obtain Site Plan Approval; No.: _____

(f) ☐ clear conditions of Site Plan Approval; No.: _____

(g) ☐ obtain approval other than that identified in (a) to (f) above; Specify _____

## 2. IDENTIFY THE APPROVING AUTHORITY FOR THIS PROJECT:

(a) ☐ Ministry of Municipal Affairs and Housing

(b) ☐ Regional Government of _____

(c) ☐ Municipal Government of _____

(d) ☐ Other (specify) _____

## 3. ATTACH PERTINENT CORRESPONDENCE:

(a) ☐ A copy of MOE's Noise Conditions for Draft Approval.

(b) ☐ The proposed plan received Draft Approval on DD_____MM_____YY_____.

(c) ☐ Letters from railways, road authorities, Municipalities, and MOE pertinent to this report.

## 4. INCLUDE THE FOLLOWING SITE PLANS:

(a) ☐ "Blue print" of site plan showing the development.

(b) ☐ Scaled plan identifying all significant noise sources, e.g. roadways, railways and industrial/commercial facilities, within a minimum of 500 m of the proposed site, and existing/future land uses abutting the proposed development. If the site is located near an airport, the plan is to show noise contours of NEF/NEP=25 and greater.

(c) ☐ If a noise barrier is used, include the following:

(i) Plan view showing location of noise barriers and elevations of the tops of the barriers.

(ii) Cross-sectional views of the barrier showing source-receiver distances and heights.

(iii) Scaled cross-section of site with the barrier.

## 5. ENSURE THAT CONTENTS OF THE REPORT INCLUDE:

(a) ☐ Description of methods used in assessing the noise impact.

(b) ☐ Summary of sound levels with and without noise control measures at receptor locations.

(c) ☐ Summary of recommended noise control measures, including warning clauses and plans to implement and verify the completion of the acoustical requirements.

## 6. FORM COMPLETED BY:

| Print Name | Signature | Company | Date |
|---|---|---|---|
| | | | |

## TOPIC 6. NOISE CONTROL MEASURES

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Describe how noise control may be implemented
2. Understand the significance of timing when implementing noise control within the proposed development
3. Know the different categories of noise control techniques
4. Appreciate the pros and cons of the use of noise barriers
5. Understand the noise control techniques related to the design of the development.

## NOISE CONTROL MEASURES

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# NOISE CONTROL MEASURES

## 1. INTRODUCTION

This chapter discusses "noise control measures" in the context of residential areas impacted by surface transportation and stationary sources of noise. The discussion focuses on noise control measures that reduce the outdoor sound levels to acceptable limits; only a brief overview of measures to protect the indoor spaces is presented. Some of the control techniques are presented here merely as suggestions to those involved in planning new housing. In any case, no simple rules can be devised regarding application of specific measures to certain types of applications, and the discussion is kept general in scope. It should be noted that the following discussion does not apply to the control for aircraft noise; this topic is discussed in the chapters dealing with acoustic insulation and noise impact assessment.

## 2. IMPLEMENTATION METHOD

The implementation of noise control measures for new housing can be viewed as a three-step process.

Step 1: Determination of sound levels at the site;

Step 2: Comparison of projected sound levels against sound level limits; and

Step 3: Design of noise control measures for excess over sound level limits.

In Step 1, the sound levels at the proposed residential development are determined by the use of applicable prediction models and techniques. The sound levels are projected to future years (usually 10 years hence) in order to fully appreciate the potential impact.

Having determined the future sound levels for the proposed site in Step 1, they are compared against the applicable sound level limits and the excess is determined. Naturally, if the levels at the site are lower than these limits, no noise control measures are required.

Step 3 involves selection of appropriate noise control measures depending on the following factors:

1. Required reduction of indoor and/or outdoor levels.
2. Timing constraints imposed by the planning process, i.e. early or late.
3. Constraints or restrictions unique to the site.

## 3. SIGNIFICANCE OF TIMING IN CONSIDERING NOISE CONTROL

In principle, there are two different design sound level criteria to be met in designing new housing: these are applicable to indoor sound levels and outdoor sound levels. Although, generally speaking, the implementation of noise control measures outdoors also affects the levels achieved indoors, these measures can be viewed as relating to two separate categories. Table 6.1 groups commonly used noise control measures under these two categories. Measures in the Table are also grouped on the basis of whether they can be considered during the early or late stages of planning the subdivision. The Table clearly indicates that the earlier noise control is considered during the process of subdivision design, the larger the selection of available control measures there will be to choose from. Thus, early consideration of noise control can conceivably reduce the costs of noise control by selecting measures which are most economical and also at the same time satisfy aesthetic and other requirements.

| Outdoor Noise Control Measures | |
|---|---|
| **Early in the Planning Process** | **Late in the Planning Process** |
| Distance setback | Earth berms |
| Insertion of insensitive buffer zone | Barrier walls and fences |
| Orientation of outdoor living areas | |
| Favourable topographical features as barriers | |
| Earth berms | |
| Barrier walls and fences | |
| Intervening structures as barriers | |
| Orientation of balconies | |

**Table 6.1 Outdoor and Indoor Noise Control Measures and the Timing of their Application in the Subdivision Planning Process**

Physical methods to reduce noise impacts on new housing can be grouped into four major categories, as shown in Table 6.2.

1. Site planning
2. Acoustical barriers

3. Architectural design
4. Construction techniques

| Noise Control Measures | | | |
|---|---|---|---|
| **Site Planning** | **Acoustical Barriers** | **Architectural Design** | **Construction Techniques** |
| Distance setbacks | Favourable topographical features as barriers | Orientation of balconies | Acoustically designed windows, walls, doors, ceilings and roofs |
| Insertion of noise insensitive buffer | Earth berms | Room and corridor arrangement | Air conditioning and ventilation |
| Orientation of outdoor living areas | Barrier walls and fences | Orientation of windows | |
| | Intervening structures as barriers | Blank walls | |

NOTE: For design purposes, vegetation including trees should not be considered as acoustical barriers.

**Table 6.2 Summary of Noise Control Measures Applicable to Design of New Housing**

## 4. ACOUSTICAL SITE PLANNING TECHNIQUES

Site planning means making use of the natural shape of the site, favourable surroundings and zoning to reduce the noise impact on proposed housing. The natural features of the site can only be utilized in reducing sound levels if noise control is considered early in the planning of the subdivision, when the flexibility is still available. In general, site planning measures are economical and very effective. Experience indicates that prudent and cost conscious planners and architects always capitalize on the use of site planning techniques.

### 4.1 DISTANCE SETBACK

Distance setback means the physical separation between the noise source and the receiver; increase in setback results in reduced outdoor sound levels. This method is most effective close to the noise source. For example, increasing the distance of a receiver from a highway from 20 m to 40 m would typically attenuate hourly Leq levels by 4 to 5 dBA. On the other hand, if the receiver were located at 80 m, to get

the same attenuation, the distance will have to be increased to 160 m. This is because the sound decay rate of a source varies logarithmically with the distance. This example illustrating the decay rate is valid not only for highway noise but also to railway noise.

Noise reduction by distance setback is usually more practicable in rural areas where land costs are lower. In most urban areas land is expensive and a distance setback alone can rarely be afforded, unless the intervening land can be used for other compatible uses.

Distance setback as a measure to reduce outdoor sound levels is available only during the earliest of stages in a subdivision design when flexibility in planning design can still be exercised.

## 4.2 INSERTION OF NOISE-INSENSITIVE BUFFER ZONES

The use of the distance setback method in urban areas is prohibitively expensive. It can, however, be made feasible if the setback strip can be put to other useful applications. Noise control by the use of a buffer zone is based on this concept. This approach offers two advantages; firstly, the setback area is utilized for a compatible land use. Secondly, additional shielding of the subdivision against noise may be provided if the buffer zone utilization calls for tall and continuous structures.

Typical land uses of the buffer strip are parking, parks, green belts and, in some cases, basketball and tennis courts. Commercial establishments such as shops, storage facilities, offices, etc. can be used as buffer zones. One such application is illustrated in Figure 6.1, the option to reduce outdoor sound levels by creating a buffer zone (i.e. a parking lot).

A similar application of a buffer is illustrated in Figure 6.2. The Figure demonstrates the effective use of a buffer zone for light industry. In the intervening parcel of land between the Electronics Plant and the single family homes is placed a non noise sensitive recreational area.

The designs illustrated in Figures 6.1 and 6.2, utilizing buffer zones, are available only during the early planning stages of the development.

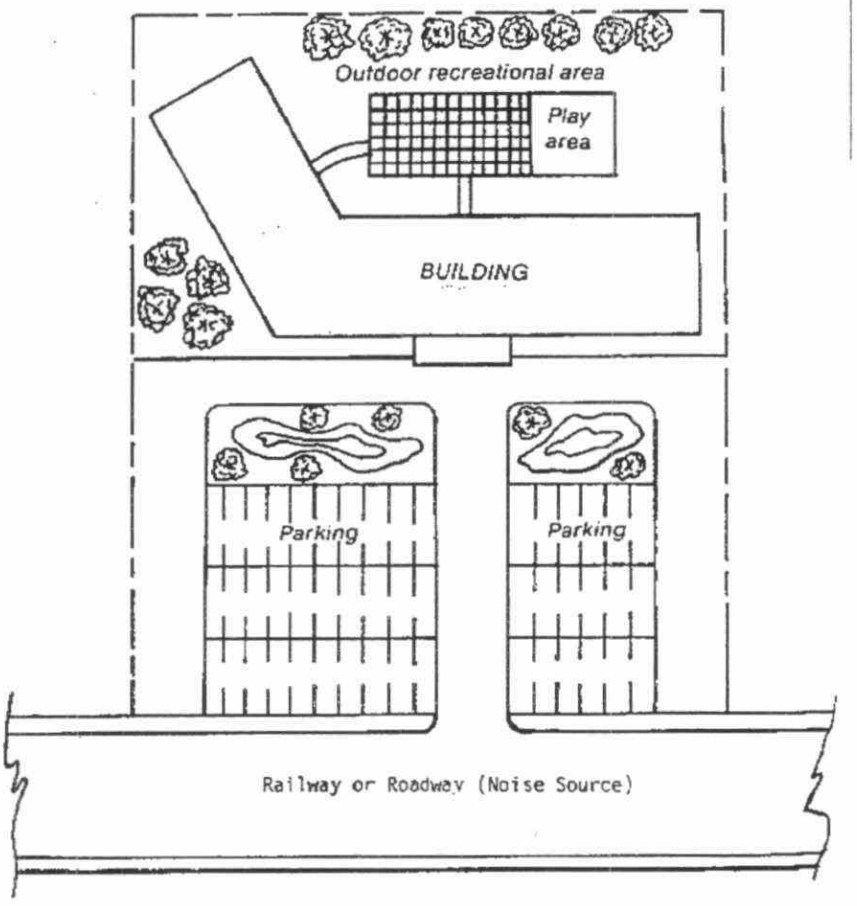


**Figure 6.1 Use of a Parking Area as a Noise Insensitive Buffer**

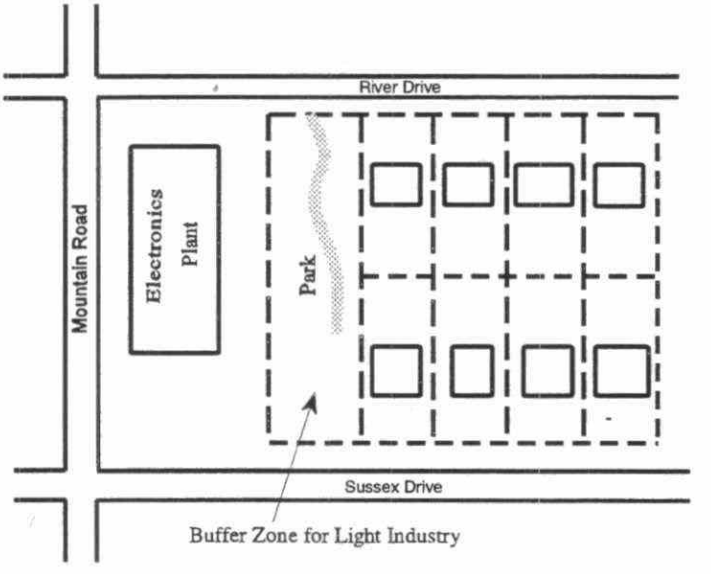


**Figure 6.2 Use of a Park as a Buffer**

## 4.3 ORIENTATION OF OUTDOOR LIVING AREAS

The requirement to provide quiet outdoor living areas for new residential development is as important as ensuring low sound levels indoors.

The backyards of dwellings are customarily used as private areas for the enjoyment of the outdoors and for passive activities such as relaxation, conversation, etc. while the front yards are usually for parking. In some cases, the house structure itself can act as a barrier between the noise source and the receiver by shielding the backyard from noise. The closer the houses, the larger the shielding. Shielding of the backyard is more effective for link housing, row housing or townhouses where the structure is continuous, parallel and close to the noise source. Short length structures of single family units are not very effective as barriers.

Two common ways of planning quiet outdoor living areas are listed below.

In one arrangement the front yard of the townhouse is located directly exposed to the noise source and the backyard in the shadow zone behind the residence. Parking and entrance to the townhouse is provided through the front yard, as shown in Figure 6.3. This application is known as single side use, internal road. Another way of arranging the recreational area is to interchange the front yard and the backyard in Figure 6.3 and then protect the backyard from the noise source by the use of a berm or wall as shown in Figure 6.4. The front yard is serviced by the internal road running parallel to the townhouses.

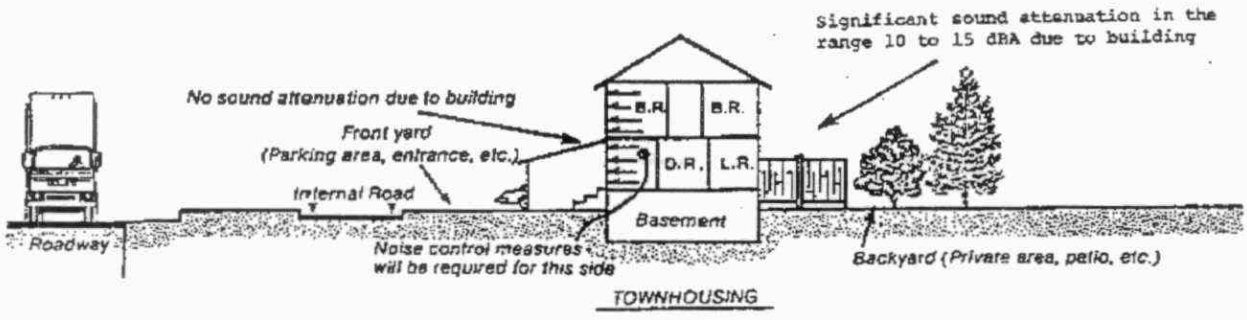


**Figure 6.3 Recreational Area (Back Yard) Shielded by the Townhouse Structure**

The second arrangement is less efficient than the first one because of the added cost of erecting and maintaining the berm and because of aesthetic reasons. The function of a berm is performed by the townhouse structure itself in the first arrangement.

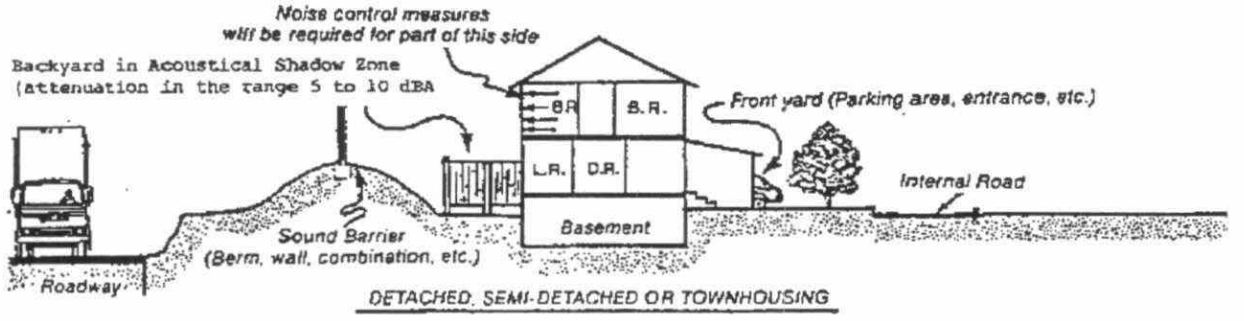


**Figure 6.4 Recreational Area (Back Yard) Shielded by the Sound Barrier**

The methods of shielding the backyard as shown in Figures 6.3 and 6.4 are not without drawbacks. The concept of employing a continuous structure to shield backyards is a restrictive one, since only rowhousing or townhouses satisfy the requirement, precluding the use of single family homes in the first row. The single side use of the internal road is inefficient and expensive because residences are located on one side of the road only.

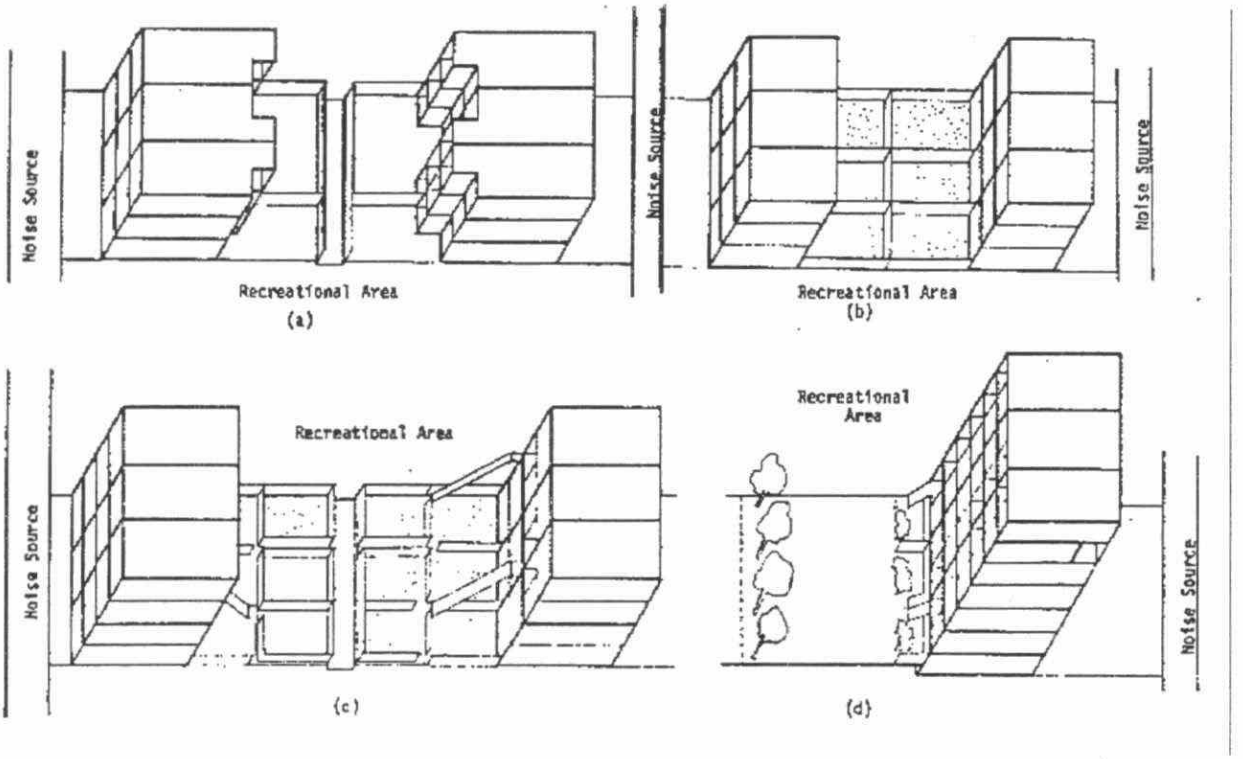


**Figure 6.5 Examples of Shielding Recreational Areas of Apartment Buildings**

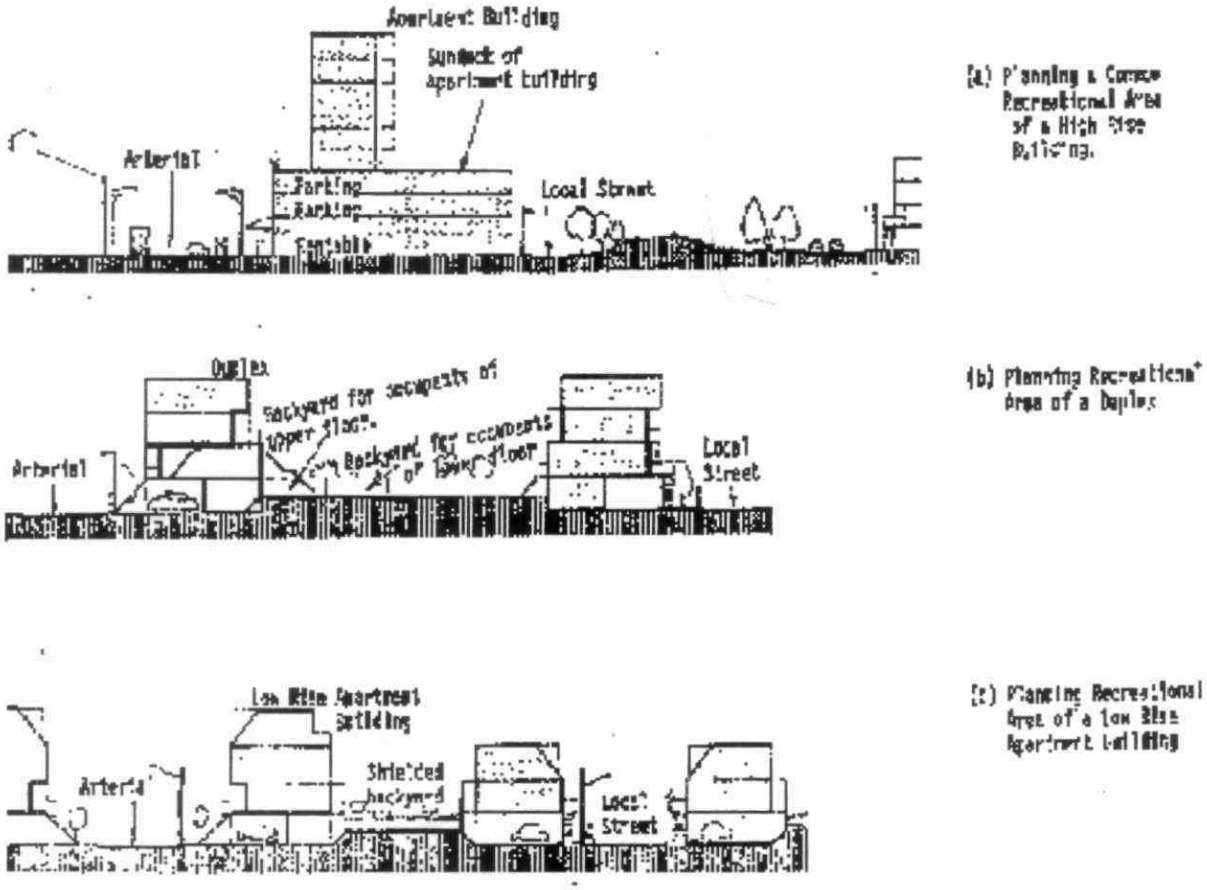


**Figure 6.6 Examples to Protect Recreational Areas of Apartment Buildings**

Figure 6.5 illustrates four of the ways of shielding outdoor living areas of apartment buildings. In all four cases the building shields the outdoor living areas from the noise source. Another variation in which the outdoor living area of an apartment building is located on the third floor and can also be used as a sundeck, as shown in Figure 6.6. The concept of shielding backyards is not just confined to more conventional forms of housing such as townhouses, rowhouses and detached homes, but also extends to other types of dwellings. In Figure 6.6 (b) the backyard of a duplex is divided into two separate areas depth wise, one being used by the occupants living upstairs and the other by the occupants on the main floor.

The planning to lower sound levels in outdoor living areas by orienting the outdoor living areas and residences must commence early in the design process. The extensive use of this method by planners is a good indicator of the wide range of possible applications and economics of controlling noise.

## 5. ACOUSTICAL BARRIER

An acoustical barrier is a physical structure, planned or natural, placed between a noise source and the noise sensitive area where reduction of sound levels is required.

Although well-designed barriers are known to be very effective in reducing sound levels, they should be considered as a secondary measure after various other site planning measures have been considered for the site and have failed to reduce the outdoor levels to the design sound level limit. Barriers are usually considered in those applications where outdoor sound levels cannot be reduced by other methods. Since certain barriers, such as berms, require valuable additional land, it is good practice to consider them early in the planning process. However, barrier walls can still be designed late into the subdivision planning process, if necessary.

The subject of barriers is discussed in more detail elsewhere in this manual but some observations with respect to the use of barriers are in order here:

(i) To be effective, barriers must be long and continuous, encircling or surrounding the area to be protected so that sound waves do not pass around the ends. This is done by ensuring that the ends of the barrier are extended well beyond the noise sensitive area. The barriers must be solid, free from gaps or holes and have adequate surface mass density [preferably not less than 20 $kg/m^2$ (4 $lb/ft^2$)].

(ii) Sound level reduction achieved due to a barrier is dependent on the path length difference, i.e. the difference between the direct distance in a straight line without a barrier and the distance measured over the top of the proposed barrier. The situation is illustrated in Figure 6.7. The barrier is most effective when it is erected either very close to the source or very close to the receiver. Another important design factor is the surface mass density of the barrier; denser barriers provide a higher amount of noise reduction. However, the mass effect has a limit of diminishing return.

(iii) To be effective a barrier must be high enough to eliminate the direct line of sight between the source and receiver. A small amount of noise reduction is obtained even if the barriers do not block the line of sight. Highest possible elevations of source and receiver should be considered in the design calculations. Figure 6.8 illustrates this point for a receiver located at ground level as well as one at the first floor level.

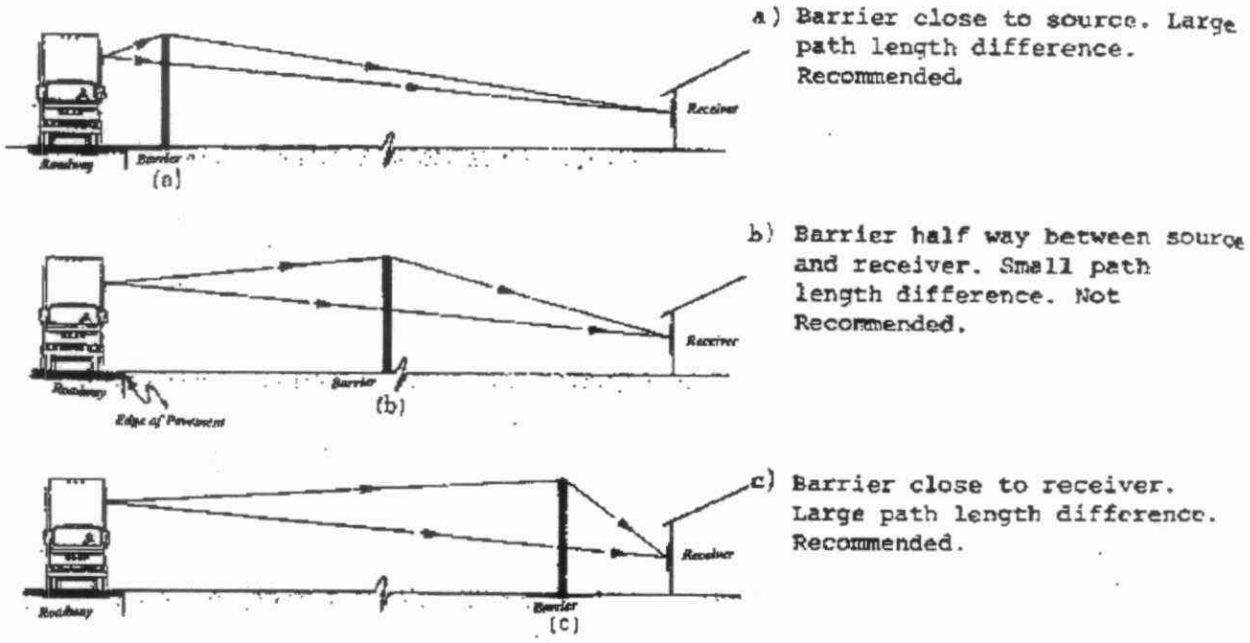


**Figure 6.7 Sound Barrier Locations with Respect to Source and Receiver**

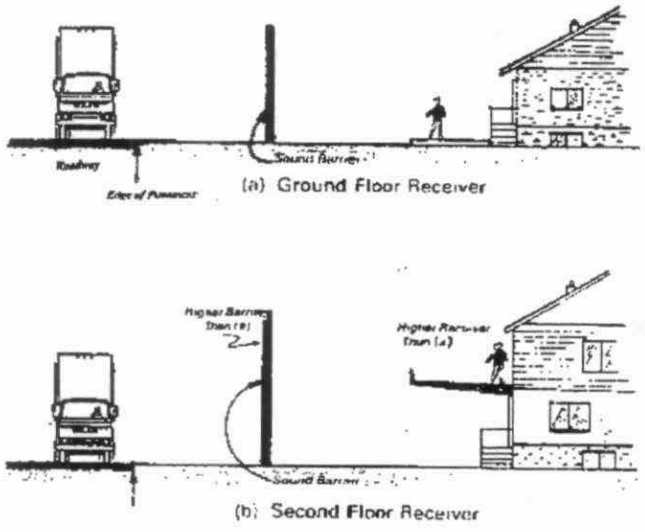


**Figure 6.8 Required Barrier Height for Two Receiver Positions**

(iv) If the barrier is properly designed, the noise problem can conceivably be minimized for the first row of sensitive receptors closest to the source and may be eliminated for the rest of the site, thus making a large portion of the site available for upgraded residential use which would not have been possible otherwise due to the hostile noise environment. As an illustration, appropriately designed rowhousing acting as a barrier may make it possible for single family houses to be planned for the

inner core of the subdivision without any special noise control measures. Thus, the effect of erecting a barrier is to reduce the area impacted by excessive outdoor sound levels.

(v) Safety must also be considered in selecting a barrier design.

(vi) Structural stability and durability of the berm-barrier, servicing, maintenance, aesthetics and erection costs are other important considerations.

(vii) Snow removal is important on the noise source side.

(viii) Some added benefits of acoustical barriers should be noted such as privacy, providing visual screening, protection against salt, slush, debris and headlight glare.

A qualitative discussion of different types of barriers follows below; barrier calculations and quantitative aspects of barrier design are covered in the Appendix.

## 5.1 TOPOGRAPHICAL FEATURES AS NATURAL BARRIERS

Existing topographical features such as valleys or ravines at a residential site can quite often be successfully exploited to act as natural barriers. Two such applications where direct line of sight between the source and receiver is eliminated and sound levels reduced by the use of favourable site topography are illustrated in Figure 6.9. In some cases topographical features can be enhanced or created at the site by excavating or land filling or by lowering the road level.

Such natural barriers utilize the given features at the site, it readily blends with the topography of a site and is aesthetically more desirable. Costs also tend to be generally smaller compared to those for the erection of berms or barriers.

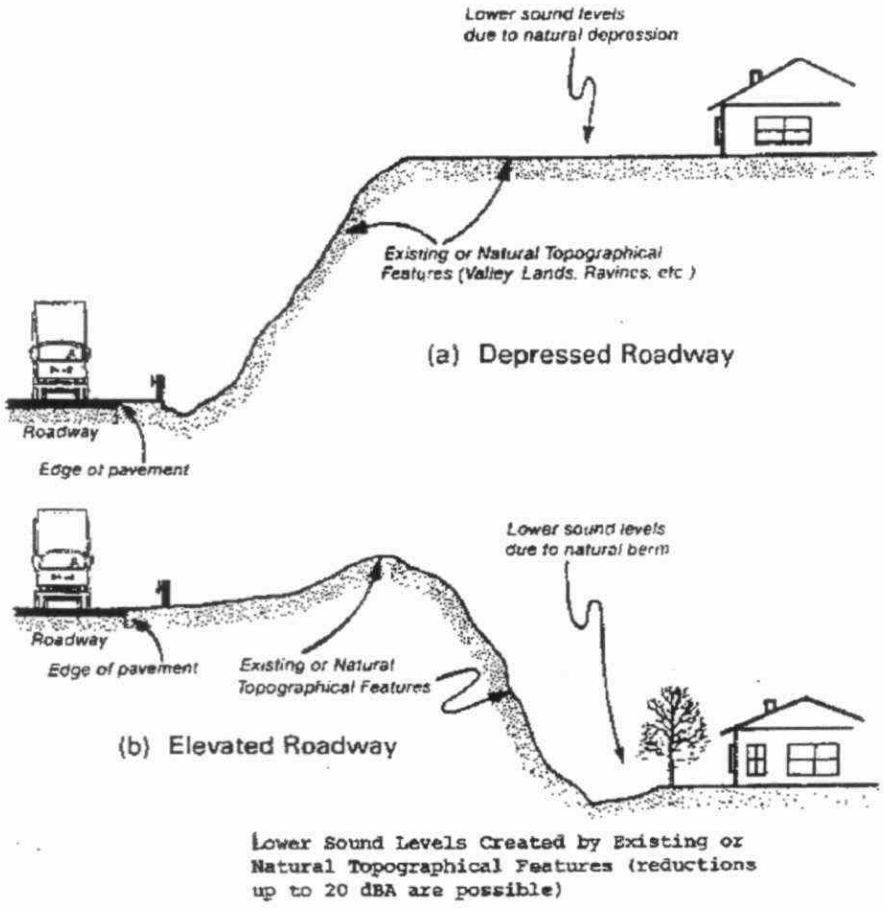


**Figure 6.9 Screening by Natural Topographical Features**

## 5.2 EARTH BERMS

An earth berm is a planned and deliberately created barrier usually made of a mound of earth running parallel to the noise source or the row of residences as shown in Figure 6.10.

Some important features of an earth berm are summarized below:

(i) Because of the sloping walls, the incident sound waves are deflected upwards and not toward the other side of the roadway as would be the case with vertical walls.

(ii) A berm provides a good absorptive surface compared to that offered by bare barrier walls, thus causing the levels of the reflected sound waves to be lower.

(iii) A berm easily meets the surface mass density requirement of 20 kg/m$^2$.

(iv) A berm can range up to four m's, or more, in height and still be designed to be satisfactory from an aesthetic viewpoint.

(v) The higher the berm the greater the volume of earth required for its construction, and the wider its base thus requiring more land for erection.

Since the erection of a berm requires land space, provisions must be made for it in the early planning stages. A shallow slope of a berm is aesthetically more acceptable, but also occupies more land and results in higher costs.

Earth berms are specifically suitable to the problem of lowering sound levels in outdoor recreational areas, although indoor levels are also reduced to some extent.

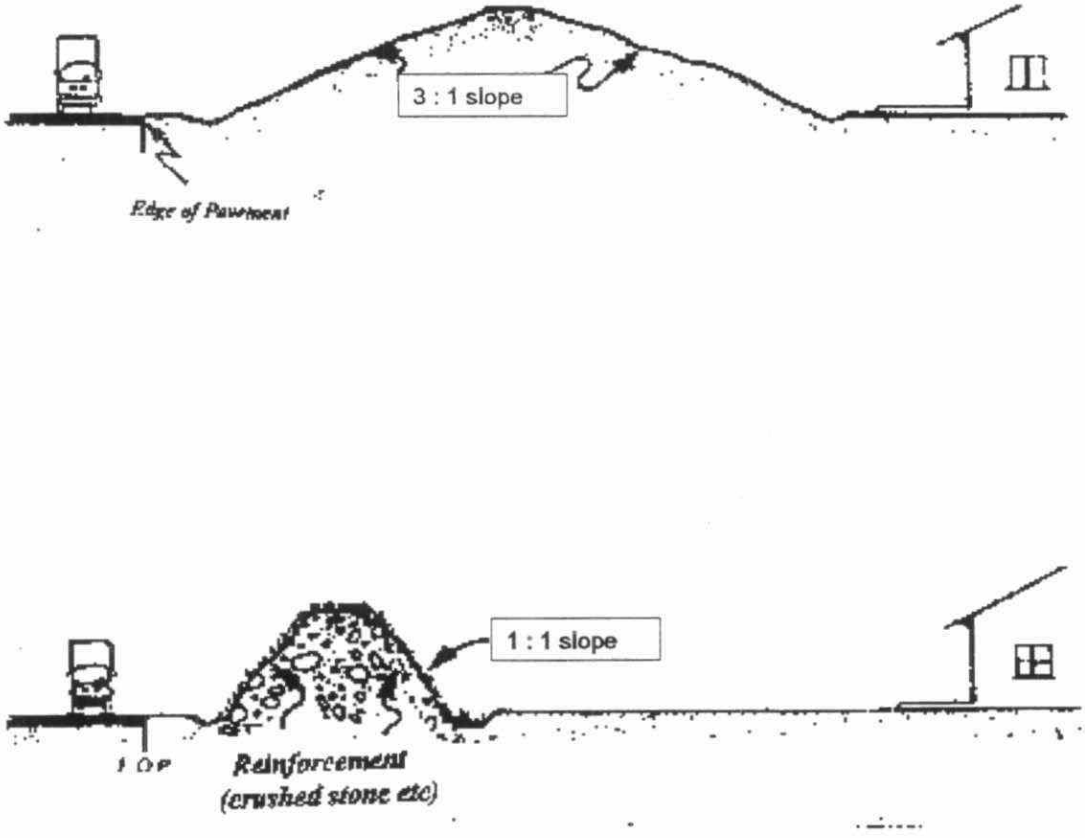


**Figure 6.10 Typical Profiles of Earth Berms**

Erection of berms as a control measure should be considered favourably if surplus earth were to become available during the construction of the subdivision at no cost. Cost of building berms includes erection

cost, maintenance expenses of cutting the grass on slopes and snow removal expenses, etc. Structural stability and durability of the berm are also major design considerations.

## 5.3 BARRIER WALLS AND FENCES

Barrier walls or fences offer the advantage of requiring a minimum of space, easy maintenance and a very strong physical separation of the subdivision from the noise source. Walls may be used to supplement the height of a berm which cannot be built taller because of structural or space considerations. Another application of a barrier wall is to shield a site for which control measures were not considered in early planning stages and, later, the land available to erect a berm is found to be inadequate.

Acoustical barrier walls can be employed early, as well as late, during the planning process to control outdoor levels. To be effective the walls must be free of gaps and holes. Concrete walls are most commonly used, followed by brick walls and sheet metal fences. One major disadvantage of barrier walls is that they are aesthetically less acceptable than berms. Structural and stability considerations are especially critical in the design of high walls (higher than 3 m).

## 5.4 INTERVENING STRUCTURES AS BARRIERS

In this method, buildings located in the first row perform the function of the noise barrier for the rest of the site. The buildings so utilized are called **barrier blocks**.

Before we discuss barrier blocks for noise control we should differentiate clearly between this method and the method of orienting the outdoor living areas, the two methods are often confused with each other. By orienting the outdoor living area in a specific way, the planner aims at providing quieter outdoor living areas for individual units or blocks. This is accomplished by rearranging these units or blocks themselves. By using an intervening structure as a barrier, the aim is to provide quieter outdoor areas not just for the residences in the first row, but for the entire site. As an illustration, shielding the backyard of a barrier block itself is considered an exercise in the orientation of the outdoor living area, while the barrier block is considered as an intervening structure to shield the rest of the site.

Among the four noise control measures discussed under the heading of acoustical barriers, barrier blocks apply most widely, and offer the most creative and elegant answer to the subdivision noise-impact problem. Some basic features of a barrier block are listed below:

(i) It is a very economical measure, since the structure in the first row performs dual functions, one as the barrier to shield the site from noise and the other to house residential, commercial or other types of activity.

(ii) Since the planner has the choice of deciding how the first row is to be utilized before it is actually built, this method offers high flexibility, provides an opportunity to ensure compatible land use and introduces interesting site diversity.

(iii) To be effective barrier blocks should be continuous and placed as close as possible to the noise source or the noise sensitive area. Thus, for a site directly exposed to the noise source, ideally the barrier block should abut the noise source. The passageways or gaps between the blocks to provide access or to fulfil fire control regulations must be minimized. Care must be taken to adequately protect the end blocks which normally have larger exposed wall areas then the inside blocks.

(iv) The barrier blocks are generally designed to be taller than the dwellings to be protected.

The widespread acceptance and use of the barrier blocks by planners and developers has resulted in many different configurations and variations being developed. Figures 6.11 and 6.12 show commercial, industrial and medium density residential buildings (townhouses) arranged in different ways along the periphery of a residential subdivision to act as a barrier block for the entire site. Reductions in the range of 10 to 17 dBA have been obtained.

The use of barrier blocks to solve noise problems is quite widespread and effective. The Ministry of the Environment and Energy highly recommends the use of barrier blocks to achieve economical and aesthetically acceptable outdoor noise control at the subdivision site. The planning for barrier blocks must begin early in the subdivision design process.

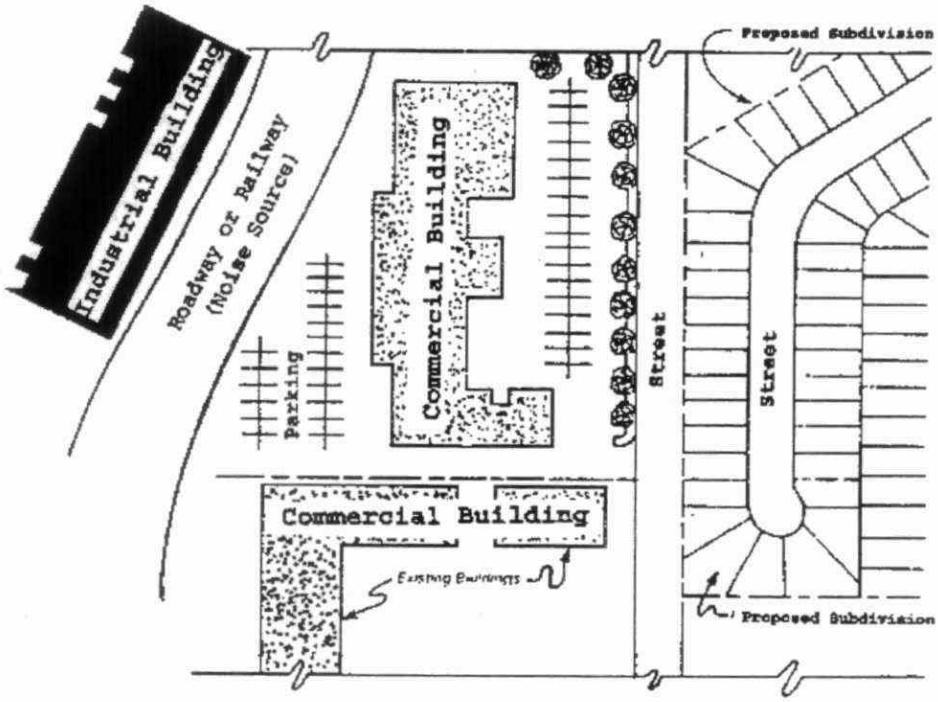


**Figure 6.11 Barrier Block Example: Commercial Building Barrier Block**

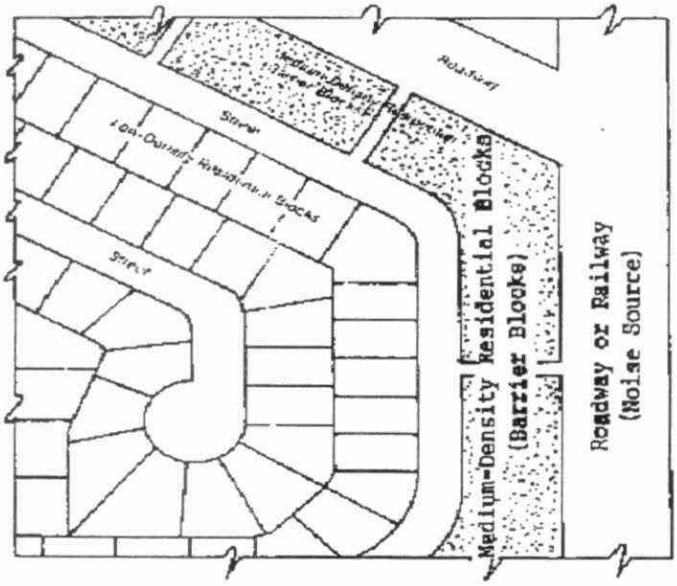


**Figure 6.12 Barrier Block Example: Residential Building Barrier Block**

## 6. DESIGN

The noise control measures discussed in this category are created and deeply influenced by the architectural design of the residential building. These measures are mostly employed to meet indoor sound level limits, although applications to reduce outdoor levels are also illustrated later. The four different types of architectural designs are discussed below.

### 6.1 ORIENTATION OF BALCONIES AND TERRACES

The concept of orienting balconies is the same as discussed under the topic of orienting the outdoor living area with one difference. The earlier discussion applies to the outdoor living areas located on the ground level (such as backyards, patios, etc.), whereas this discussion concentrates on the outdoor living areas located at higher elevations. Examples of such areas are terraces of the high and medium rise apartment buildings and stacked townhouses which are more closely integrated with the architectural design of the residences than those discussed previously.

As with the backyards and the patios in the earlier case, they should be placed on the shielded side of the building. This solution, however, can only be applied to one side of a dual-aspect or double-loaded building because of the excessive noise exposure on the other side.

Shielding of the outdoor area by locating it in the acoustical shadow of the building to reduce levels is an inexpensive measure easily adopted during the early planning stages.

### 6.2 ROOM AND CORRIDOR ARRANGEMENTS

Indoor sound levels in the noise sensitive areas of the home can be substantially lowered by arranging the less sensitive rooms and spaces adjacent to the exposed walls. The noise sensitive areas include bedrooms, living rooms and dens where sleep, speech communication and relaxation activities take place. By comparison, kitchens and bathrooms are considered to be less noise sensitive. Examples of uses which are not at all sensitive to noise are closets, storage rooms, corridors, stairways, etc.

With the use of good planning principles applied in the early stages of the floor-plan design, the problem of noise exposure of the occupants of the home can be effectively solved at practically no added cost.

### 6.3 ORIENTATION OF WINDOWS

Indoor sound levels can be lowered by providing the windows on the walls which are not directly exposed to the noise source. The effectiveness of this measure depends on the orientation of the wall with respect

to the noise source. If the wall with the windows in it is parallel to the noise source on the shielded side of the house, significant reduction of indoor levels can be realized. For windows designed in the walls running perpendicular to the noise sources, the reduction is expected to be slight.

There is no added cost involved in orienting the windows on the unexposed walls. This measure is quite effective in controlling indoor levels and can be considered early as well as late during the planning process. Consideration should also be given to the orientation of windows with respect to exposure to sunlight.

## 6.4 BLANK WALLS

From the noise insulation viewpoint, the window is the weaker link of a wall-window combination. For dwellings exposed to very high sound levels the exposed walls should be windowless. This is done by relocating the windows to other walls subjected to lower sound levels. The blank walls find application in the high density housing (high rise apartments), stacked townhouses and also for the low and medium density housing (detached homes, townhouses, rowhouses, etc.). An example of the former is illustrated in Figure 6.13 where the apartment building is facing an industrial facility. The wall of the building that is directly exposed to the industrial noise is the blank wall and the windows are provided only on the shielded side. An example of indoor noise control by providing a blank wall for a townhouse is shown in Figure 6.14.

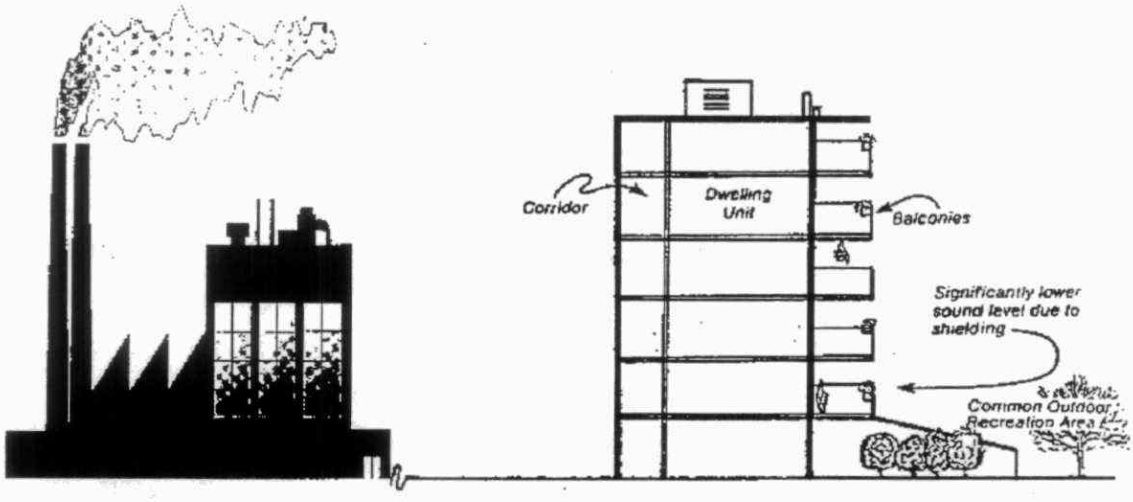


**Figure 6.13 Blank Wall in Apartment Buildings - Single Loaded Building**

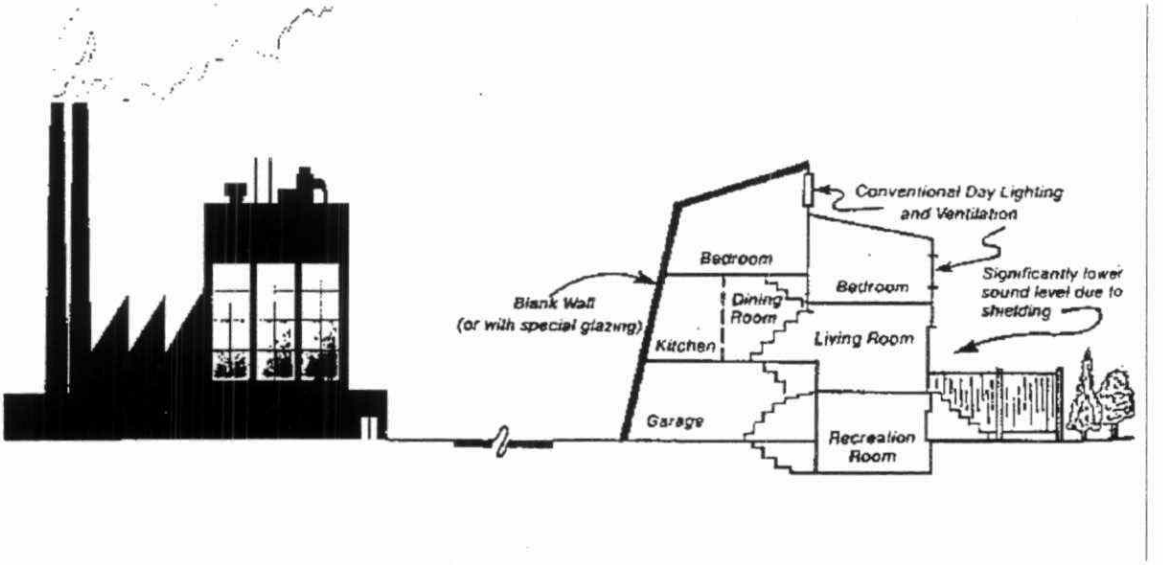


**Figure 6.14 Blank Wall in Townhouse Buildings**

The use of blank walls imposes two restrictions. The conventional house plan normally relies on openable windows located in opposite walls to provide adequate lighting and ventilation. With the use of one blank wall the flexibility to provide windows is somewhat reduced and care must be taken to ensure sufficient lighting and ventilation. One such alternative is to design units to be slightly wider than normal. The other restriction is that apartment buildings with one blank wall are "one side" loaded, resulting in the corridors, and passageways being underutilized.

The application of blank walls should only be confined to the extreme cases where the noise problem is too serious to be resolved by other measures. The likelihood of poor lighting and ventilation dictates that this measure be used with the utmost discretion and only as a last resort.

Significant reduction of sound levels indoors is possible with the use of blank walls. The measure can be used early as well as late during the subdivision planning process. The cost of this measure may, in fact, range anywhere between slightly lower to somewhat higher than the cost of a wall window combination.

## 7. CONSTRUCTION TECHNIQUES

If indoor sound levels cannot be lowered sufficiently by the design of the architectural features, further reduction is possible by employing special construction materials and techniques. To minimize the cost of noise control these measures should only be considered after the various architectural features favourable to the noise reduction have been fully explored.

## 8. CASE HISTORIES

The following cases illustrate the way the noise control measures can be incorporated into new housing plans. This does not necessarily constitute an endorsement of the approach but demonstrates the practicability of the various measures and their potential applications by the planners and architects.

### 8.1 TOWNHOUSE DEVELOPMENT EXPOSED TO TRAIN NOISE

Townhouses were planned for a subdivision in a location exposed to train noise. Initially, the site plan was prepared without due consideration to the noise control measures, as shown in Figure 6.15. Outdoor sound levels could not comply with the criteria over the most part of the subdivision. The 3 m and 6 m buffer zones were virtually ineffective in providing any noise reduction. In Figure 6.16 the buffer zones were eliminated, and the townhouses were arranged in the form of a long and near continuous barrier block, running parallel to the train tracks. As a result the outdoor living areas for the entire subdivision were substantially shielded against train noise. It should be noted that the land yield has remained unchanged at 116 units after rearrangement and, in fact, the outdoor noise problem was solved without incurring any additional cost.

In addition to addressing the outdoor noise issues, the structural components of the dwellings have to be appropriately designed to ensure that the indoor noise complies with the criteria. Furthermore, depending on the outdoor sound levels, air conditioning may have to be provided. The subject of sound transmission from outdoor to indoor and the acoustical insulation of building components are discussed in the chapter dealing with acoustical insulation.

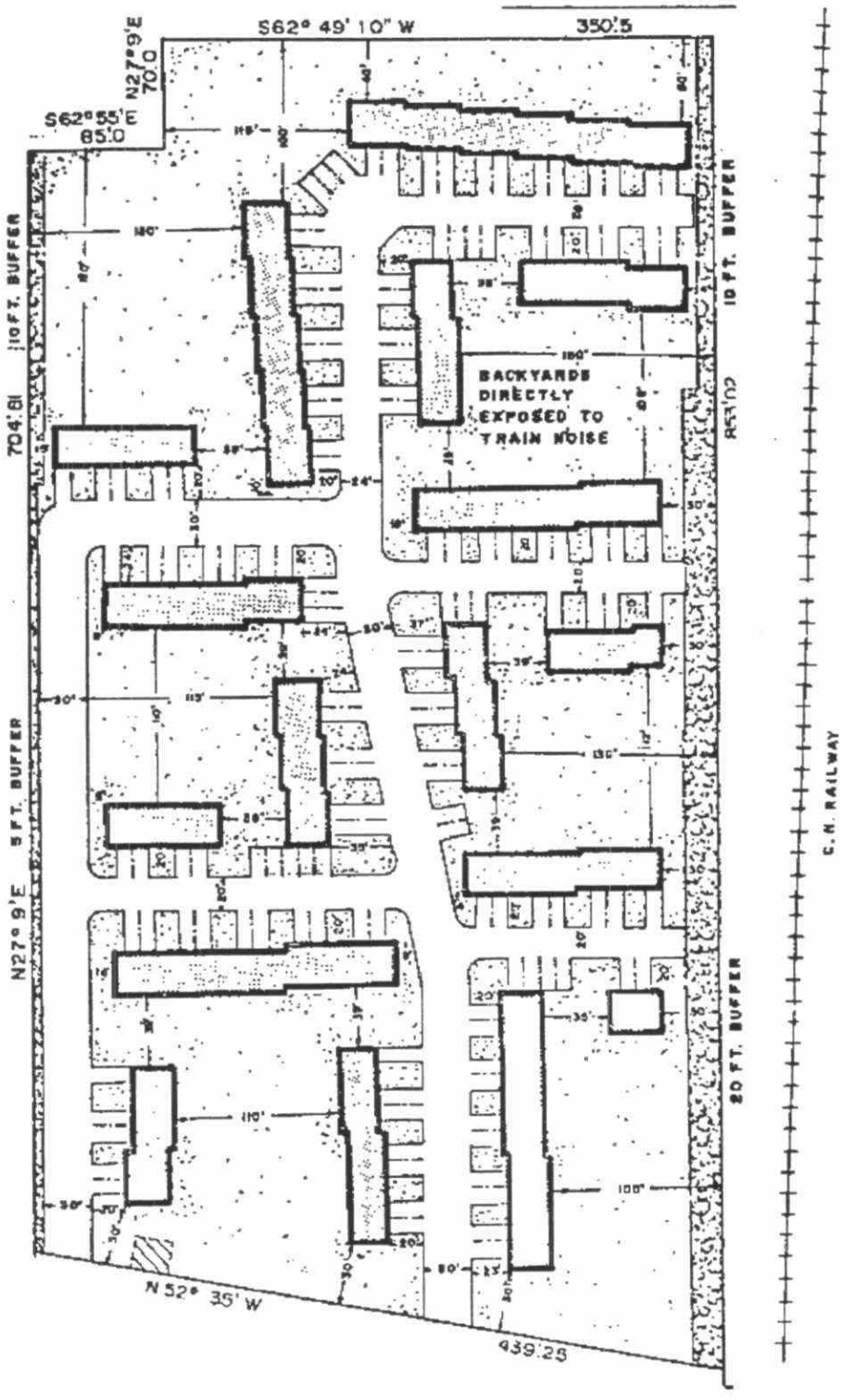


**Figure 6.15 Case Study - Inadequate Noise Control Measures**

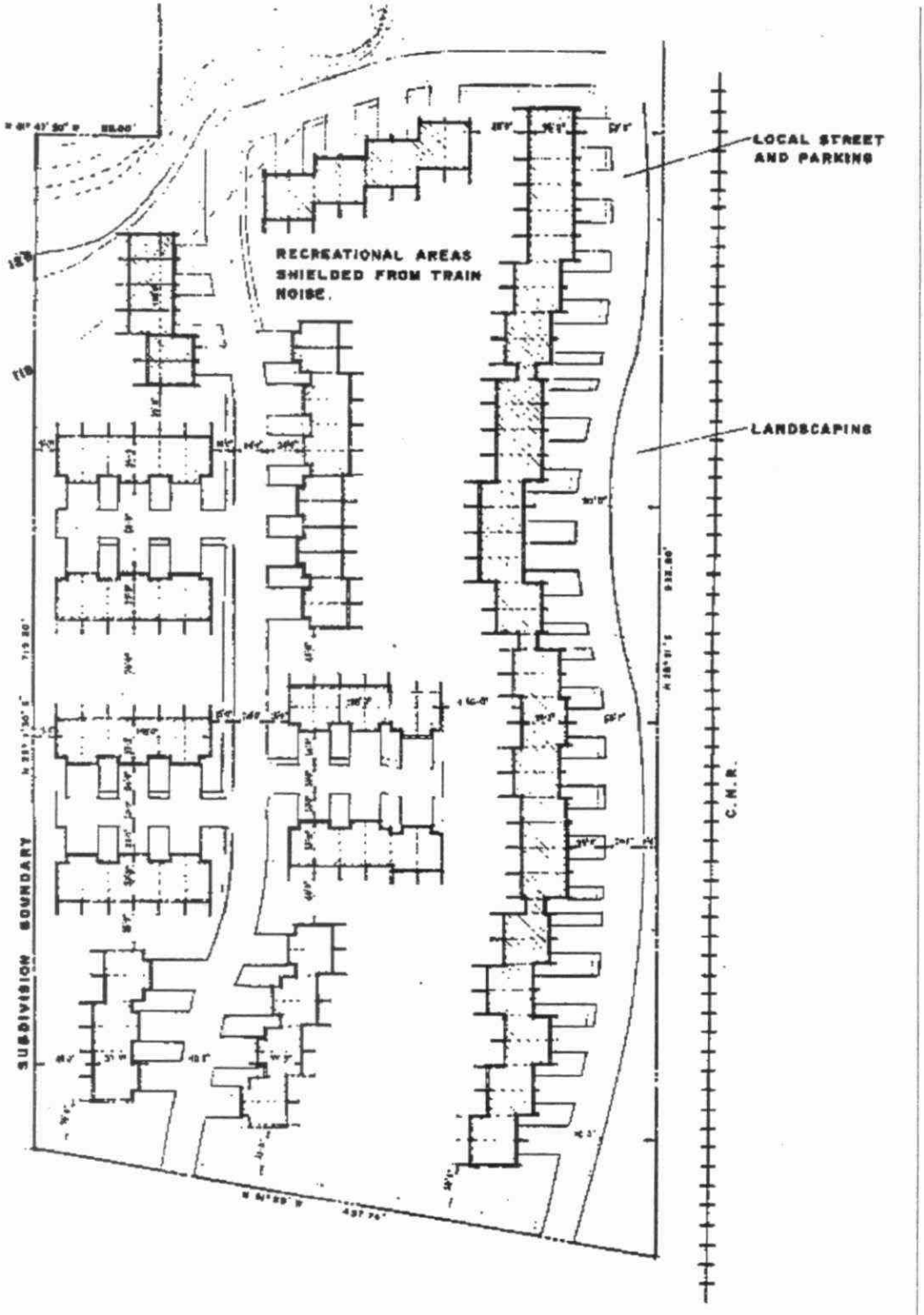


**Figure 6.16 Case Study - Adequate Noise Control Measures**

## TOPIC 7. ACOUSTICAL INSULATION

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Know the principles of acoustic insulation
2. Know the methods for estimating the required acoustics insulation
3. Understand the principles of the AIF method
4. Understand the principles of the STC method
5. Calculate the required acoustic insulation using both the AIF and STC methods.

## ACOUSTICAL INSULATION

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# ACOUSTICAL INSULATION

## 1. INTRODUCTION

Urban areas contain a very large number of buildings that are located adjacent to airports or transportation corridors. In order to control the transmission of noise into the indoor environments, the building design has to include the principles of acoustical insulation. Depending on the outdoor sound levels, the building components such as walls and windows must be selected to ensure that appropriate indoor sound levels are achieved: acoustically better components are required to protect against higher outdoor sound levels.

Two methods of calculating the acoustical insulation are available for design purposes: the older method, in use since the late 1970s, is based on the Acoustic Insulation Factor (AIF); a more recent method, published in 1985, is based on the Sound Transmission Class (STC) of building components. Both methods have been developed by the National Research Council of Canada and the MOE accepts the use of both methods.

Although not specifically covered in this chapter, the acoustical design of buildings must be complemented by a properly designed ventilation system.

### 1.1 CORRECTION FOR FACADE REFLECTIONS

In principle, the effect of reflective surfaces such as building facades is to increase the sound levels immediately adjacent to those surfaces. The question is how or whether to incorporate this effect into the calculation methods.

As both the outdoor sound level criteria and the prediction (calculation) methods for transportation noise are representative of free-field sound levels, no corrections for facade reflections in the calculation of outdoor impacts are necessary.

However, the circumstances are different when determining indoor sound levels and the required acoustical insulation. In principle, acoustical insulation is based on the sound transmission loss of components forming the building's exterior envelope, and the determination of the transmission loss assumes that a diffused sound field exists on both sides of the building component. The standardized method for determining the sound transmission of exterior facades requires that the sound level on the exterior side (source side) of the component is to be measured at a distance of 2 m from the facade in order to approximate the diffused field. The sound level at 2 m from the facade is higher than the free-field sound level because it includes the direct sound field (free-field sound level) as well as the reflected sound field;

therefore, 3 dB must be added to the free-field sound level calculated using the standard prediction methods when determining the required acoustical insulation of the building components.

This reflection correction factor of +3 dB is implicitly included in the AIF method, described in Section 3. The values of AIF in Tables 7.1 and 7.2 include this 3 dB adjustment and therefore no further adjustment is necessary. In the STC method, however, the +3 dB correction factor must be added separately. The details of the AIF and STC procedures are given in Sections 3 and 4.

## 2. DESIGN OF VENTILATION REQUIREMENTS

The design values of acoustical insulation for the exterior building components assume that windows and doors are closed and fully weatherstripped; the acoustical insulation effectiveness with opened windows or doors is considerably lower. In order to allow the windows and doors to remain closed, some form of mechanical means of ventilation is generally required to provide air movement and remove heat and moisture.

The requirement for central air conditioning (alternate means of ventilation) is based upon a condition that, with opened windows, the indoor sound level criteria in the sleeping as well as living areas should not be exceeded by more than 10 dB. For example, if the indoor sound level criterion (closed windows) is 40 dBA, central air conditioning would be required if the indoor sound level with opened windows exceeded 50 dBA. Furthermore, the criterion on the outdoor "free-field" level for central air conditioning requirement is based on evidence that a typical "open window" provides a noise reduction of approximately 10 dB when compared to the "free-field" outdoor level. Consequently, an outdoor "free-field" sound level exceeding 60 dBA outside a bedroom window triggers a requirement for central air conditioning

## 3. THE AIF METHOD

The outdoor-to-indoor sound transmission and the requirements for sound insulation could be evaluated using first principles by determining the sound levels outside the building and all the transmission paths into the building. However, such evaluation would involve lengthy calculation of the sound energy transmitted through the various paths at various frequencies. To simplify this procedure, the National Research Council of Canada developed a simplified technique that evaluates the insulation requirements of residential housing near airports and transportation corridors. The appropriate building components are selected on the basis of the Acoustic Insulation Factor (AIF) which is related to the difference in indoor and outdoor levels.

## 3.1 FORMULATION

### 3.1.1 Aircraft Noise

The Acoustic Insulation Factor (AIF) for aircraft noise analysis is given by:

$$AIF = NEF^{*}_{outdoors} - (required)\ NEF_{indoors} + 10 \log_{10} N$$

where N = number of components forming the exposed facade (door, wall, window and ceiling) of the room

NEF = Noise Exposure Forecast value ( * Use NEP if applicable )

This AIF factor takes into account the number of components forming the envelope of the room, and the NEF (Noise Exposure Forecast) contour value at the building location.

### 3.1.2 Road and Rail Noise

The Acoustic Insulation Factor (AIF) for road and rail noise analysis is obtained from:

$$AIF = L_{A,\ outdoors} - (required)\ L_{A,\ indoors} + 10\ Log_{10}\ N + 2$$

where $L_A$ = A-weighted sound level due to road or rail traffic

N = the number of components forming the exposed facade of the room

The AIF method was originally developed for aircraft noise; due to source spectrum differences, the sound insulation property of a building exposed to road or rail noise is typically less than that exposed to aircraft noise. The term +2 in the equation is used to account for this difference.

## 3.2 AIF CALCULATION PROCEDURE

### 3.2.1 General Principles

Typically, the outdoor noise may penetrate a room through several possible paths; one or more walls, windows, doors, and in the case of aircraft noise, the roof. To sum up the contributions of these various paths would require a complex calculation of absolute powers. The calculation is simplified by postulating that all paths carry equal sound power. If follows from this simplified assumption that the AIFs for all components within the same general path (corrected for an area) are equal.

Although in principle one could compensate for a low AIF in one path by a superior value in another, the lowest ones always dominate, and the equal power postulate may thus be conservative by one or two points at most. If there are several transmission paths, each must carry less power than if there were only one path which is taken into account by increasing the AIF requirement by three points for two paths, five for three paths, etc.

The result is an optimum design that keeps the relative importance of the major construction elements in perspective. The one parameter allowed to be altered over wide limits is the ratio of window to wall area. The final step is to provide a series of tables of AIF values for typical building components.

### 3.2.2 Detailed Procedure for Aircraft Noise

The appropriate building components for any room in a dwelling are selected as follows:

(a) Determine from the NEF/NEP contour maps the NEF/NEP contour passing through the building location. The contour maps are in intervals of 5 NEF points. If the building location falls between two NEF/NEP contours, the higher value should be used.

(b) Determine the type of room for which the AIF is required: bedroom or other room.

(c) Determine the number of components which make up the exterior envelope of the room from windows, walls, ceiling/roofs and doors. It should be noted that:

  (i) Where the windows and exterior doors do not form part of the exterior envelope of a room, they must be treated and included as a component of all rooms which have an opening or doorway opposite or adjacent to them.

  (ii) Since the AIF is related to the total area of each type of component, the number of individual components of each type does not affect the AIF calculation. For example, six individual windows in a room are counted as one component, combining their total area in the calculation.

  (iii) An example is shown in Figure 7.1: Bedroom 1 has two walls, three windows and ceiling. The number of components for Bedroom 1 is actually three (wall, window and roof-ceiling).

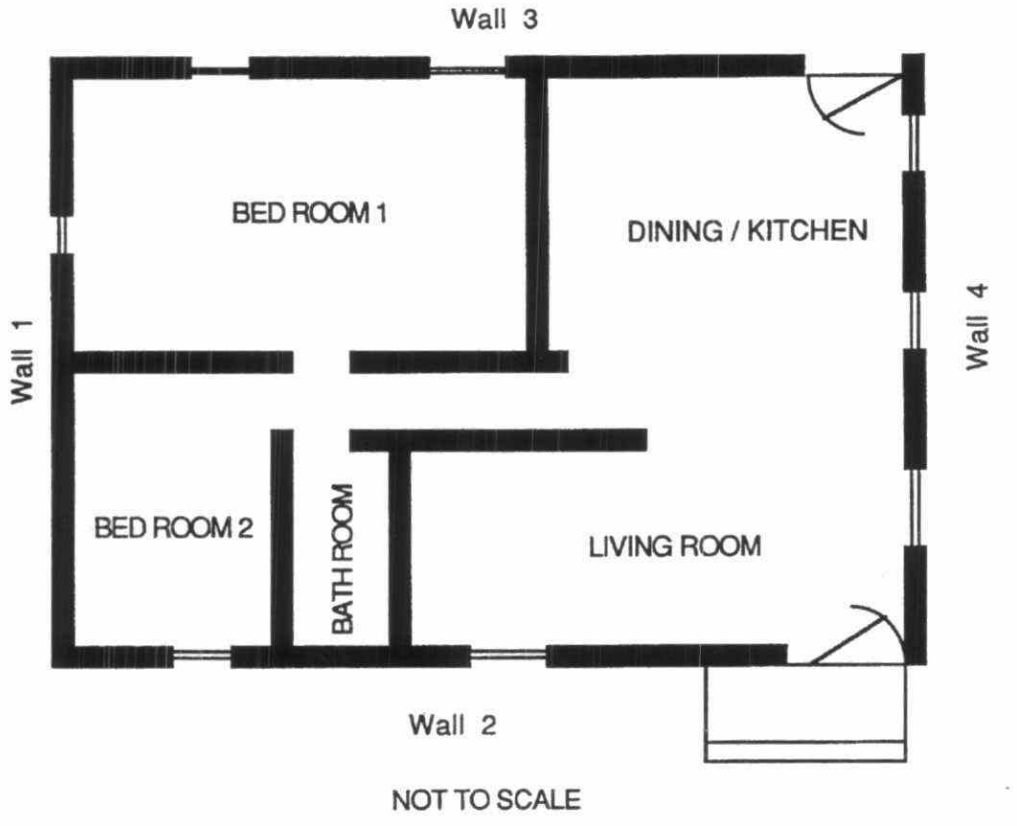



**Figure 7.1 Plan of a Two Bedroom Bungalow**

(d) Determine the AIF from Table 7.1

| Number of components, N forming the building envelope | AIF (Bedrooms) | AIF (Living/Dining) |
|---|---|---|
| 1 components | NEF + 0 | NEF - 5 |
| 2 components | NEF + 3 | NEF - 2 |
| 3 components | NEF + 5 | NEF |
| 4 components | NEF + 6 | NEF + 1 |

**Table 7.1 Selection of AIF Values for Aircraft Noise**

(i) The required Acoustic Insulation Factors given by the NEF value and by (NEF - 5) for bedrooms and living rooms respectively, see Table 7.1, have been recommended by the National Research Council of Canada, based on a review of studies related to thresholds of annoyance and speech interference. They are related to acceptable indoor noise levels

equivalent to 0 NEF units and +5 NEF units for bedrooms and other rooms respectively. The difference of five units between the two types of accommodations allows for the desirability of having less noise in sleeping quarters (bedrooms).

(e) Select the appropriate types of windows, exterior walls, ceiling-roof and exterior door respectively from Tables 7.3, 7.4, 7.5 and 7.6 using the obtained AIF value. Where the calculated AIF does not correspond directly to the AIF value given in the table, the next highest AIF value should be used.

(f) If a component is chosen whose AIF exceeds the required value by 10 or more, that component shall not be included in the number of elements when determining the AIF required for the other components of the room envelope.

Where a window or exterior door type has been determined in relation to more than one room, the selection shall comply with the highest standard so calculated.

### 3.2.3 Detailed Procedure for Road and Rail Traffic Noise

The appropriate building components for any room in a dwelling are selected as follows:

(a) Determine, by prediction methods the sound level $L_A$, dBA produced by road and rail traffic at the exterior wall. The evaluated sound level must be adjusted for shielding as described in Section 3.4.

(b) Determine whether the required AIF is for the components of a bedroom or other less noise sensitive room.

(c) Determine the number of components which make up the exterior envelope of the room from windows, walls and doors. It should be noted that:

(i) Roofs are ignored in the calculation as conventional designs provide sufficient noise reduction.

(ii) If the noise level at the wall is 55 dBA or less, the components of that wall are not included in the calculation.

(iii) The actual number of doors or windows does not affect the determination of the AIF, since the AIF is related to the total area of these components for each wall.

(iv) Where a room has more than one exterior wall, the number of components for each exterior wall is determined and these numbers are added to obtain the number of components for the room.

(v) An example is shown in Figure 7.1. Bedroom 1 has two walls and three windows. The total number of components is actually four (two walls, and two windows). We have assumed that walls 1 and 3 have predicted noise levels in excess of 55 dBA. If, for instance, wall 3 has noise level less than 55 dBA, the number of components for Bedroom 1 reduces to two (one wall and one window).

(d) Determine the AIF from Table 7.2.

(e) The computed AIF must be adjusted for noise source geometry as described in Section 3.5.

(f) The appropriate types of windows, exterior wall, ceiling-roof and exterior door respectively are selected from Tables 7.3, 7.4, 7.5 and 7.6 using the obtained AIF value. Where the calculated AIF does not correspond directly to the AIF value given in the table, the next highest AIF value should be used.

(g) If a component is chosen whose AIF exceeds the required value by 10 or more, that component shall not be included in the number of elements when determining the AIF required for the other components of the room envelope.

| Sound Level at Building Facade (dBA) | AIF Values for Road Traffic Noise | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Components Forming Room Envelope | | | | | | | | | | | | | | |
| | Bedroom | | | | | Living, Dining, Recreation | | | | | Kitchen, Bathroom | | | | |
| | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 60 | 22 | 25 | 27 | 28 | 29 | 17 | 20 | 22 | 23 | 24 | 12 | 15 | 17 | 18 | 19 |
| 61 | 23 | 26 | 28 | 29 | 30 | 18 | 21 | 23 | 24 | 25 | 13 | 16 | 18 | 19 | 20 |
| 62 | 24 | 27 | 29 | 30 | 31 | 19 | 22 | 24 | 25 | 26 | 14 | 17 | 19 | 20 | 21 |
| 63 | 25 | 28 | 30 | 31 | 32 | 20 | 23 | 25 | 26 | 27 | 15 | 18 | 20 | 21 | 22 |
| 64 | 26 | 29 | 31 | 32 | 33 | 21 | 24 | 26 | 27 | 28 | 16 | 19 | 21 | 22 | 23 |
| 65 | 27 | 30 | 32 | 33 | 34 | 22 | 25 | 27 | 28 | 29 | 17 | 20 | 22 | 23 | 24 |
| 66 | 28 | 31 | 33 | 34 | 35 | 23 | 26 | 28 | 29 | 30 | 18 | 21 | 23 | 24 | 25 |
| 67 | 29 | 32 | 34 | 35 | 36 | 24 | 27 | 29 | 30 | 31 | 19 | 22 | 24 | 25 | 26 |
| 68 | 30 | 33 | 35 | 36 | 37 | 25 | 28 | 30 | 31 | 32 | 20 | 23 | 25 | 26 | 27 |
| 69 | 31 | 34 | 36 | 37 | 38 | 26 | 29 | 31 | 32 | 33 | 21 | 24 | 26 | 27 | 28 |
| 70 | 32 | 35 | 37 | 38 | 39 | 27 | 30 | 32 | 33 | 34 | 22 | 25 | 27 | 28 | 29 |
| 71 | 33 | 36 | 38 | 39 | 40 | 28 | 31 | 33 | 34 | 35 | 23 | 26 | 28 | 29 | 30 |
| 72 | 34 | 37 | 39 | 40 | 41 | 29 | 32 | 34 | 35 | 36 | 24 | 27 | 29 | 30 | 31 |
| 73 | 35 | 38 | 40 | 41 | 42 | 30 | 33 | 35 | 36 | 37 | 25 | 28 | 30 | 31 | 32 |
| 74 | 36 | 39 | 41 | 42 | 43 | 31 | 34 | 36 | 37 | 38 | 26 | 29 | 31 | 32 | 33 |
| 75 | 37 | 40 | 42 | 43 | 44 | 32 | 35 | 37 | 38 | 39 | 27 | 30 | 32 | 33 | 34 |
| 76 | 38 | 41 | 43 | 44 | 45 | 33 | 36 | 38 | 39 | 40 | 28 | 31 | 33 | 34 | 35 |
| | AIF Values for Rail Traffic Noise | | | | | | | | | | | | | | |
| 55 | 22 | 25 | 27 | 28 | 29 | 17 | 20 | 22 | 23 | 24 | 12 | 15 | 17 | 18 | 19 |
| 56 | 23 | 26 | 28 | 29 | 30 | 18 | 21 | 23 | 24 | 25 | 13 | 16 | 18 | 19 | 20 |
| 57 | 24 | 27 | 29 | 30 | 31 | 19 | 22 | 24 | 25 | 26 | 14 | 17 | 19 | 20 | 21 |
| 58 | 25 | 28 | 30 | 31 | 32 | 20 | 23 | 25 | 26 | 27 | 15 | 18 | 20 | 21 | 22 |
| 59 | 26 | 29 | 31 | 32 | 33 | 21 | 24 | 26 | 27 | 28 | 16 | 19 | 21 | 22 | 23 |
| 60 | 27 | 30 | 32 | 33 | 34 | 22 | 25 | 27 | 28 | 29 | 17 | 20 | 22 | 23 | 24 |
| 61 | 28 | 31 | 33 | 34 | 35 | 23 | 26 | 28 | 29 | 30 | 18 | 21 | 23 | 24 | 25 |
| 62 | 29 | 32 | 34 | 35 | 36 | 24 | 27 | 29 | 30 | 31 | 19 | 22 | 24 | 25 | 26 |
| 63 | 30 | 33 | 35 | 36 | 37 | 25 | 28 | 30 | 31 | 32 | 20 | 23 | 25 | 26 | 27 |
| 64 | 31 | 34 | 36 | 37 | 38 | 26 | 29 | 31 | 32 | 33 | 21 | 24 | 26 | 27 | 28 |
| 65 | 32 | 35 | 37 | 38 | 39 | 27 | 30 | 32 | 33 | 34 | 22 | 25 | 27 | 28 | 29 |
| 66 | 33 | 36 | 38 | 39 | 40 | 28 | 31 | 33 | 34 | 35 | 23 | 26 | 28 | 29 | 30 |
| 67 | 34 | 37 | 39 | 40 | 41 | 29 | 32 | 34 | 35 | 36 | 24 | 27 | 29 | 30 | 31 |
| 68 | 35 | 38 | 40 | 41 | 42 | 30 | 33 | 35 | 36 | 37 | 25 | 28 | 30 | 31 | 32 |
| 69 | 36 | 39 | 41 | 42 | 43 | 31 | 34 | 36 | 37 | 38 | 26 | 29 | 31 | 32 | 33 |
| 70 | 37 | 40 | 42 | 43 | 44 | 32 | 35 | 37 | 38 | 39 | 27 | 30 | 32 | 33 | 34 |
| 71 | 38 | 41 | 43 | 44 | 45 | 33 | 36 | 38 | 39 | 40 | 28 | 31 | 33 | 34 | 35 |
| 72 | 39 | 42 | 44 | 45 | 46 | 34 | 37 | 39 | 40 | 41 | 29 | 32 | 34 | 35 | 36 |
| 73 | 40 | 43 | 45 | 46 | 47 | 35 | 38 | 40 | 41 | 42 | 30 | 33 | 35 | 36 | 37 |
| 74 | 41 | 44 | 46 | 47 | 48 | 36 | 39 | 41 | 42 | 43 | 31 | 34 | 36 | 37 | 38 |
| 75 | 42 | 45 | 47 | 48 | 49 | 37 | 40 | 42 | 43 | 44 | 32 | 35 | 37 | 38 | 39 |
| 76 | 43 | 46 | 48 | 49 | 50 | 38 | 41 | 43 | 44 | 45 | 33 | 36 | 38 | 39 | 40 |

**Table 7.2 AIF Requirements for Road and Rail Traffic Noise**

## 3.3 SELECTION OF BUILDING COMPONENTS

The following tables relate the various types of components to the required AIF:

Table 7.3 Window AIF. Use of the table requires a calculation of the percentage of the total window area of a room to the total floor area of that room.

Table 7.4 Exterior wall AIF. Use of the table requires a calculation of the percentage of total exterior wall area of a room (less window and doors) to the total floor area of that room.

Table 7.5 Ceiling-roof AIF.

Table 7.6 Exterior door AIF. Use of the table requires a calculation of the percentage of the total door area of a room to the total floor area of that room.

Tables 7.3 through 7.6 have been compiled by the National Research Council of Canada from laboratory tests on various components. These may be revised from time to time as methods and standards of construction change, and as results of a series of field tests become available and are evaluated.

## 3.4 SHIELDING ADJUSTMENT

The prediction methods ORNAMENT and STEAM evaluate the free-field noise level. Any wall of a building might be shielded from the noise source. Appropriate shielding corrections must therefore be applied. A factor of -3 dB is applied to the free-field sound level at walls that are perpendicular to the source. A -15 dB correction is applied to the free-field sound level at the wall which is opposite to the directly exposed wall.

| Window area as a percentage of total floor area of room [1] | | | | | | | | | | | | | | Single glazing | Double glazing of indicated glass thickness | | | | | Triple glazing | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 5 | 6 | 8 | 10 | 13 | 16 | 20 | 25 | 32 | 40 | 50 | 63 | 80 | | 2 mm & 2 mm glass | 3 mm & 3 mm glass | 4 mm & 4 mm glass | 3 mm & 6 mm glass | 6 mm & 6 mm glass | 3 mm, 3 mm and 3 mm glass | | 3 mm, 3 mm and 6 mm glass | |
| Acoustic Insulation Factor (AIF) [2] | | | | | | | | | | | | | | Thickness | Interpane spacing in mm [3] | | | | | Interpane spacing in mm [5] | | | |
| 35 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 2 mm | 6 | | | | | | | | |
| 36 | 35 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | | 13 | | | | | | | | |
| 37 | 36 | 35 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 3 mm | 15 | 6 | | | | | | | |
| 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 4 mm-4 mm | 18 | 13 | 6 | | | | | | |
| 39 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | 27 | 26 | | 22 | 16 | 13 | 6 | 6 | 6 | 6 | | |
| 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | 27 | 9 mm [4] | 28 | 20 | 16 | 13 | 13 | 6 | 10 | 6 | 6 |
| 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | | 35 | 25 | 20 | 16 | 16 | 6 | 15 | 6 | 10 |
| 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | 30 | 29 | 12 mm [4] | 42 | 32 | 25 | 20 | 20 | 6 | 20 | 6 | 15 |
| 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | 30 | | 50 | 40 | 32 | 25 | 24 | 6 | 30 | 6 | 20 |
| 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | | 63 | 50 | 40 | 32 | 30 | 6 | 40 | 6 | 30 |
| 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | | 80 | 63 | 50 | 40 | 37 | 6 | 50 | 6 | 40 |
| 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | | 100 | 80 | 63 | 55 | 50 | 6 | 65 | 6 | 50 |
| 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | | 125 | 100 | 80 | 75 | 70 | 6 | 80 | 6 | 65 |
| 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | | 150 | 125 | 100 | 95 | 90 | 6 | 100 | 6 | 80 |
| 49 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | | | 150 | 125 | 100 | 100 | | | 6 | 100 |
| 50 | 49 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | | | | 150 | 135 | 125 | | | | |

Source: National Research Council, Division of Building Research, June 1980

Explanatory Notes:

1) Where the calculated percentage window area is not presented as a column heading, the nearest percentage column in the table values should be used.

2) AIF data listed in the table are for well-fitted, weather stripped units that can be opened. The AIF values apply only when the windows are closed. For windows fixed and sealed to the frame, add three (3) to the AIF given to the table.

3) If the interpane spacing or glass thickness for a specific double-glazed window is not listed in the table, the nearest listed values should be used.

4) The AIF ratings for 9 mm and 12 mm glass are for laminated glass only; for solid glass, subtract two (2) from the AIF values listed in the table.

5) If the interpane spaces for a specific triple-glazed window are not listed in the table, use the listed case whose combined spacings are nearest to the actual combined spacing.

6) The AIF data listed in the table are for typical windows, but details of glass mounting, window seals, etc., may result in slightly different performance for some manufacturers' products. If a laboratory sound transmission loss data (conforming to ASTM test method E-90) are available, these should be used to calculate the AIF.

7) For easy reference, glazing dimensions are written in the form 2 (100) 2 to denote 2 mm glass (100 mm space) 2 mm glass in the examples.

**Table 7.3 Acoustical Insulation Factors (AIF) for Various Types of Windows**

| | Percentage of exterior wall area to total floor area of room | | | | | | | | | | | Type of Exterior Wall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 16 | 20 | 25 | 32 | 49 | 50 | 63 | 80 | 100 | 125 | 160 | |
| Acoustic Insulation Factor | 39 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | 30 | 29 | EW1 |
| | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | EW2 |
| | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | EW3 |
| | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | EW4 |
| | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | EW1R |
| | 49 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | EW2R |
| | 50 | 49 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | EW3R |
| | 55 | 54 | 53 | 52 | 51 | 50 | 49 | 48 | 47 | 46 | 45 | EW5 |
| | 56 | 55 | 54 | 53 | 52 | 51 | 50 | 49 | 48 | 47 | 46 | EW4R |
| | 58 | 57 | 56 | 55 | 54 | 53 | 52 | 51 | 50 | 49 | 48 | EW6 |
| | 59 | 58 | 57 | 56 | 55 | 54 | 53 | 52 | 51 | 50 | 49 | EW7 or EW5R |
| | 63 | 62 | 61 | 60 | 59 | 58 | 57 | 56 | 55 | 54 | 53 | EW8 |

Source: National Research Council, Division of Building Research, December 1980

Explanatory Notes:

1) Where the calculated percentage window area is not presented as a column heading, the nearest percentage column in the table values should be used.
2) The common structure of walls EW1 to EW5 is composed of 12.7 mm gypsum board, vapour barrier, and 38 x 89 studs with 50 mm (or thicker) mineral wool or glass fibre batts in inner-stud cavities.
3) EW1 denotes exterior wall as in Note 2), plus sheathing, plus wood siding or metal siding and fibre backer board.
   EW2 denotes exterior wall as in Note 2), plus rigid insulation (25-30 mm), and wood siding or metal siding and fibre backer board.
   EW3 denotes simulated mansard with structure as in Note 2), plus sheathing, 28 x 89 mm framing, sheathing, and asphalt roofing material.
   EW4 denotes exterior wall as in Note 2), plus sheathing and 20 mm stucco.
   EW5 denotes exterior wall as in Note 2), plus sheathing, 25 mm air space, 100 mm brick veneer.
   EW6 denotes exterior wall composed of 12.7 mm gypsum board, rigid insulation (25 - 50 mm), 100 mm back-up block, 100 mm face brick.
   EW7 denotes exterior wall composed of 12.7 mm gypsum board, rigid insulation (25 - 50 mm), 140 mm back-up block, 100 mm face brick.
   EW8 denotes exterior wall composed of 12.7 mm gypsum board, rigid insulation (25 - 50 mm), 200 mm concrete.
4) R signifies the mounting of the interior gypsum board on resilient clips.
5) An exterior wall conforming to rainscreen design principles and composed of 12.7 mm gypsum board, 100 mm concrete block, rigid insulation (25 - 50 mm), 25 mm air space, and 100 mm brick veneer has the same AIF as EW6.
6) An exterior wall described in EW1 with the addition of rigid insulation (25 - 50 mm) between the sheathing and the external finish has the same AIF as EW2.

**Table 7.4 Acoustical Insulation Factors (AIF) for Various Types of Exterior Walls**

| Acoustic Insulation Factor | Type of Ceiling-Roof |
|---|---|
| 41 | C1 |
| 44 | C1R or C1D |
| 47 | C2 or C1DR |
| 49 | C3 |
| 50 | C2D |
| 52 | C2DR |

Source: National Research Council, Division of Building Research, December 1980

Explanatory Notes:

1) C1 denotes 12.7 mm gypsum board, 75 mm (or thicker) insulation batts, flat roof joists and beam construction, built-up roofing.

2) C2 denotes 12.7 mm gypsum board, 75 mm (or thicker) insulation batts, typical wood roof truss with ventilated attic, sheathing and asphalt roofing.

3) C3 denotes paint finish, 150 mm concrete slab, 50 mm rigid insulation, built-up roofing.

4) D signifies the addition of a second layer of 12.7 mm gypsum board.

5) R signifies mounting the gypsum board on resilient clips.

6) DR signifies the addition of a second layer of gypsum board mounted on resilient clips.

**Table 7.5 Acoustical Insulation Factor for Various Ceiling/Roof Combinations (Aircraft Noise Only)**

| | Percentage of total door area to total floor area of room | | | | | | | | | Type of Exterior Door |
|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6.3 | 8 | 10 | 12.5 | 16 | 20 | 25 | |
| Acoustic Insulation Factor | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | D1 |
| | 34 | 33 | 32 | 31 | 30 | 29 | 28 | 27 | 26 | D2 |
| | 36 | 35 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | D3 |
| | 37 | 36 | 35 | 34 | 33 | 32 | 31 | 30 | 29 | D4 |
| | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | 30 | D5 or D1-sd |
| | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | D2-sd |
| | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | D3-sd |
| | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | D4-sd |
| | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | D5-sd |
| | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | D3-D3 |
| | 50 | 49 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | D5-D5 |

Source: National Research Council, Division of Building Research, December 1980

Explanatory Notes:

1) Where the calculated percentage door area is not presented as a column heading, the nearest percentage column in the table values should be used.

2) All prime doors must be fully weatherstripped.

3)
- D1 denotes 45 mm hollow core wood door (up to 20% of area glazed).
- D2 denotes 45 mm glass-fibre reinforced plastic door with foam or glass-fibre insulated core (up to 20% of area glazed).
- D3 denotes 35 mm in solid slab wood door.
- D3 denotes 45 mm in steel door with foam or glass-fibre insulated core.
- D4 denotes 45 mm in solid slab door.

4) sd denotes storm door of wood or aluminum with openable glazed sections. The AIF values apply when the glazed sections are closed.

**Table 7.6 Acoustical Insulation Factor (AIF) for Various Types of Exterior Doors**

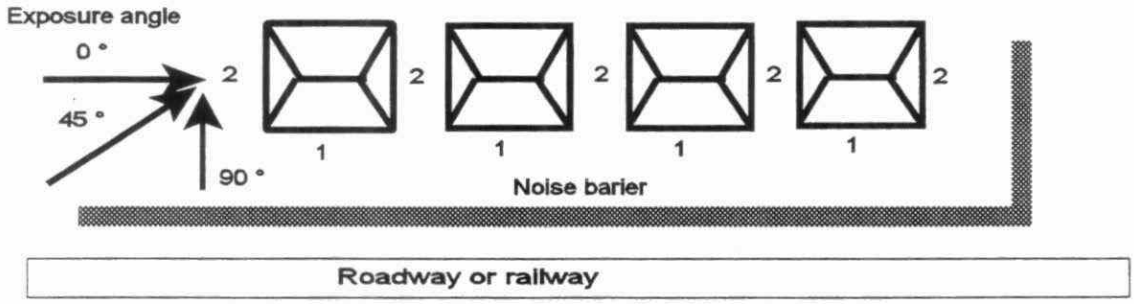
## 3.5 EFFECT OF SOURCE GEOMETRY

The AIF is used to select the appropriate building components if the outside noise level near the proposed building exceeds sound level limits. AIF is a composite number which is determined among others by the transmission loss of the building component. The transmission loss of the wall, window, roof or door is usually determined by laboratory methods where the incident sound field is diffused. Such a sound field

is commonly denoted as Random Incident Field. The transmission loss value is nearly zero if the sound field impinges on the component at grazing incidence. In the case of the sound field incident only along a narrow range of angles at grazing incidence the transmission loss value decreases. An example is that of an exterior wall of a single family dwelling which is perpendicular to a roadway or a railway track (e.g. exterior surface 2 in Figure 7.2). The required AIF values in this case must be adjusted accordingly. Figures 7.2 and 7.3 show the geometry and the adjustment values are given in Table 7.7.

| Angles at which sound arrives at facade (0 degrees means perpendicular to facade) | Correction $C_1$ dB |
|---|---|
| 60 to 90 degrees | 3 |
| 40 to 90 degrees | 2 |
| 30 to 90 degrees | 1 |
| 0 to 90 degrees | 0 |

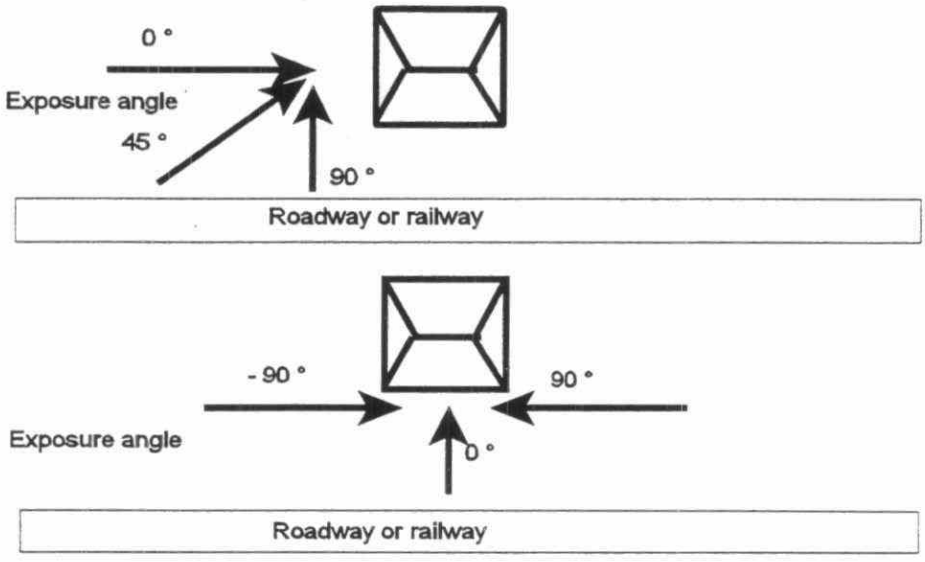
**Table 7.7 Correction (Term $C_1$) for Source Geometry: Added to Required AIF**




Surfaces 1 are parallel to the road and fully exposed
Geometry correction is zero.

Surfaces 2 are perpendicular to the road:
Geometry correction is necessary. The value depends on the exposure angle.

**Figure 7.2 Exposure Angles for Geometry Correction**




The angular range best describing the dominant noise should be used..

The exposure angles are measured from the perpendicular to the affected facade.

**Figure 7.3 Exposure Angles for Geometry Correction**

## 3.6 EQUIVALENT BUILDING COMPONENTS

Where building components other than those selected on the basis of AIF (from Tables 7.3 through 7.6) are included in the building design, it is essential to investigate whether they are acoustically equivalent. Such an evaluation will require estimation of the AIF value for the proposed equivalent component and comparison to the AIF value for the component selected from the appropriate Tables 7.3 through 7.6. The proposed component is considered acoustically equivalent if its AIF number is equivalent to or greater than the AIF value for the component calculated from the tables.

The MOE accepts the use of alternate materials for building components, as long as the alternate material has an AIF value which is equivalent to or better than the required material. Equivalent 'AIF' implies that the transmission loss values, particularly in the lower frequency end of the spectrum must be at least equal. The various standards provide methods to establish the transmission loss values in frequency range from 125 Hz to 4000 Hz in 1/3 octave band steps. The comparison of transmission loss values in the standardized frequency range is more than adequate for most of the sources. For some sources, such as locomotives generating strong low frequency sound components, the frequency spectrum may be extended down to the 63 Hz or 80 Hz bands. The transmission loss values at the low frequencies must, therefore, be evaluated from field measurements or tested by theoretical prediction methods.

## 3.7 OFFICES

In the case of a commercial development or industrial buildings with office space, the MOE advises that the AIF computed for "other rooms" be reduced by 5 AIF units in order to account for the decreased sensitivity of offices as compared to living rooms.

## 3.8 AIF CALCULATION EXAMPLE

An example is presented to illustrate the AIF method. It concerns a three bedroom bungalow; the noise source is a busy regional road. The details are given in Figure 7.4 and the calculations are in Worksheets 1 and 2. Bedrooms 1 and 2 are chosen for illustrative purposes.

The amount of sound insulation that is required to reduce the exterior sound is calculated first. The second stage is to select suitable components using the building component areas and the required AIF. The components are chosen from Tables 7.3 through 7.6.

The exterior walls and windows needed for Bedroom 1 are commonly used materials that satisfy Ontario Building Code (OBC) requirements. Any materials may be utilised as long as they comply with the OBC requirements. The window for Bedroom 2 is not standard; a special double glazed window with 20 mm gap is required. The wall of Bedroom 2 that faces the source is required to be slightly better than conventional walls; that is, it should be constructed with at least wood or metal siding and fibre backed board with rigid insulation.

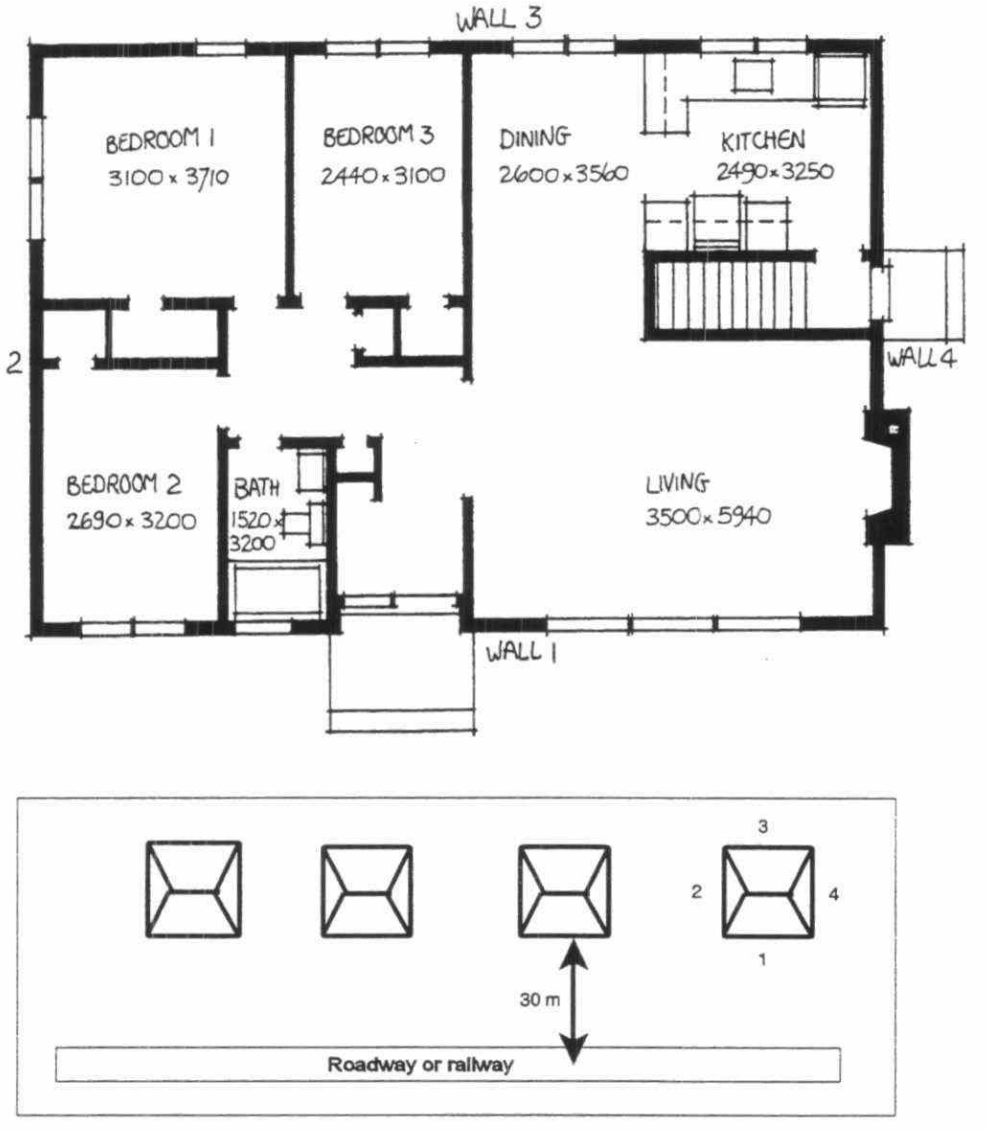



**Figure 7.4 Example of a Bungalow**

## Source: Road Traffic

**Predicted free-field night-time sound level = 68 dBA**

STEP 1: Determine the sound level at the building facade

| | WALL 1 | WALL 2 | WALL 3 | WALL 4 |
|---|---|---|---|---|
| Source 1 | 68 | 68 | 68 | 68 |
| Shielding Correction | - | - 3 | - 15 | - 3 |
| Resultant Sound Level | 68 | 65 | 53 | 65 |

STEP 2: Determine the number of components (ignore if sound level below 55 dBA)

| ROOM | WALL 1 | | | WALL 2 | | | WALL 3 | | | WALL 4 | | | TOTAL NUMBER OF COMPONENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WIND | WALL | DOOR | WIND | WALL | DOOR | WIND | WALL | DOOR | WIND | WALL | DOOR | |
| Living/dining | ✓ | ✓ | ✓ | | | | | | | | ✓ | | 4 |
| Kitchen | | | | | | | | | | | ✓ | ✓ | 2 |
| Bedroom 1 | | | | ✓ | ✓ | | | | | | | | 2 |
| Bedroom 2 | ✓ | ✓ | | | ✓ | | | | | | | | 3 |
| Bedroom 3 | | | | | | | | | | | | | - |
| Basement | | ✓ | | ✓ | ✓ | | | | | ✓ | ✓ | | 5 |

STEP 3: Determine AIF from Table 7.2

| | WALL 1 | WALL 2 |
|---|---|---|
| Bedroom 1 | - | 30 |
| Bedroom 2 | 35 | 32 |

STEP 4: Determine Adjustment for Geometry from Table 7.7

| | WALL 1 | WALL 2 |
|---|---|---|
| Exposure Angle | 0 -90 | 40 - 90 |
| Adjustment | 0 | 2 |

STEP 5: Determine the required AIF (add step 3 to step 4)

| | WALL 1 | WALL 2 |
|---|---|---|
| Bedroom 1 | - | 32 |
| Bedroom 2 | 35 | 34 |

**Worksheet 1 Calculation of AIF**

## Source: Road Traffic (cont.)

STEP 1: Enter the component area in $m^2$
(only components within exterior walls are included in the calculation)

| ROOM | WALL 1 | | | WALL 2 | | | ROOM FLOOR AREA |
|---|---|---|---|---|---|---|---|
| | WIND | WALL | DOOR | WIND | WALL | DOOR | |
| Bedroom 1 | | | | 1.4 | 6.9 | | 11.5 |
| Bedroom 2 | 1.6 | 4.4 | | | 7.4 | | 8.6 |

STEP 2: Determine component percentages (use values from Step 1)

| | | | | | | |
|---|---|---|---|---|---|---|
| Bedroom 1 | | | | 12 | 60 | |
| Bedroom 2 | 19 | 51 | | | 86 | |

STEP 3: Select components (components percentages from Step 2 and AIF values from Step 5 of Worksheet 1)
Use Tables 7.3 through 7.6

| | | | | | | |
|---|---|---|---|---|---|---|
| Bedroom 1 | | | | 3 (6) 3 mm | EW1 | |
| Bedroom 2 | 3 (32) 3 mm | EW2 | | | EW2 | |

**Worksheet 2 Selection of Components**

## 4. THE STC METHOD

The AIF method described in Section 3 allows for the evaluation of the acoustical insulation requirements and the selection of appropriate building components. An alternative to the AIF method is a method utilizing the Sound Transmission Class (STC) of building components. This method was also developed by the National Research Council of Canada and is discussed in detail in an NRC publication BPN 56, Control of Sound Transmission into Buildings, published in September 1985. The following presents a brief outline of the "STC method".

The Sound Transmission Class (STC) is the most commonly used rating method for sound insulation in North America. The STC method has the following major advantages over the AIF method discussed in the previous section:

- The AIF method is based on a single source sound spectrum (aircraft noise) whereas the STC procedure can be used for six different common noise sources and can also be extended for other sources with a known sound spectrum.

- The AIF method assumes typical room absorption values based on a reverberation time of 0.5 sec. (In fact, studies have found that the average reverberation time in Canadian homes is lower, about 0.4 sec, across the frequency spectrum.) The STC method allows for three user selected room absorption values to be used in the calculation.

- The AIF method assumes that each component of the exterior facade transmits the same percentage of the outdoor acoustic energy and corrections for dominant component are not straightforward. The STC method allows the users to take advantage of the fact that typical walls and ceilings have higher STC ratings than windows and doors.

The procedure outlined below is a five step method taking into consideration the amount of noise reduction needed, source spectrum, source geometry, etc. The method is usually used to select relevant components of the exterior surface but it can also be used for reverse calculation where the potential Noise Reduction is determined from a given set of components. The reverse procedure is useful in evaluating the modification to existing design. The five steps of the STC method are:

1. Determine the required Noise Reduction (NR) from the outside sound level and the required inside sound level.
2. Apply correction for multiple components.
3. Apply correction for source geometry.
4. Apply correction for multiple components.
5. Apply correction for component area and room absorption.

## 4.1 GENERAL PROCEDURE

Only a brief summary is presented in this section. For details, refer to BPN 56. The appropriate building components for any room in a dwelling are selected as follows:

(a) Using a prediction method, determine the outdoor sound level at the exterior facade:

- By reference to the NEF/NEP airport contour map, determine the NEF/NEP contour passing through the building location. If the location falls between two NEF/NEP contours, the higher value should be used. Convert the NEF/NEP value to the equivalent sound level $L_A$ (dBA), using:

$$L_A = \text{NEF/NEP} + 31, \text{ dBA}$$

- Predict the sound level $L_A$ (dBA) at the exterior wall due to road traffic.

- Predict the sound level $L_A$ (dBA) at the exterior wall due to rail traffic.

- The sound level prediction methods provide only the "free-field" sound field from the source. **When using the STC method, add 3 dB to the level $L_A$, evaluated in Step (a) for aircraft, road and rail traffic, to account for the effect of reflected energy.**

(b) Select the applicable indoor sound level limit for aircraft, road or rail noise and calculate the required Noise Reduction:

$$\text{NR} = \text{Outside Sound Level } L_A - \text{Indoor Sound Level Limit}$$

(d) Evaluate the correction term $C_1$ for source geometry, given in Table 7.7.

(e) Evaluate the correction term for multiple components. The exterior sound transmits into the room through several components such as doors, windows, walls and roof. The average sound level in the room depends on the amount of sound energy transmitted by each component. Since individual components may have different STC values, the sound energy transmitted by a component depends on its STC and its area. The correction term $C_2$ for the amount of transmitted energy is given in Table 7.8. Assume that equal energy is transmitted through each of the various components. If a particularly good (acoustically) component is chosen, say a wall with STC rating higher than the one required, the sound energy transmitted through the other components could be increased. [The example in Section 4.4 presents the procedure.]

(f) Evaluate the correction term for component area and room absorption. The amount of sound energy transmitted into the room depends on the component STC and its area. In addition, the amount of sound energy reduced by the component depends on the difference between the sound entering the room and the sound absorbed by the room furnishings. The correction term $C_3$ is given in Table 7.9.

A bedroom with thick carpets, heavy drapes and upholstered furniture is described as "very absorptive". A typical kitchen or bathroom is "hard". Intermediate cases include a dining room or a living room with minimal carpeting.

(g) Evaluate the correction term $C_4$ for source spectrum. The STC test method is based on middle and high frequency ranges. Building components typically have a low noise reduction at low frequencies. Many of the transportation sources contain sound energy at low frequencies and the STC values must be corrected. The source spectra for six typical transportation sources are given in Figure 7.5. The correction term $C_4$ for the source spectrum for a number of exterior surfaces is given in Table 7.10.

(h) Evaluate the required STC (for the applicable noise source) as shown below.

$$STC_{required} = \textit{Exterior Sound Level } L_{eq} - \textit{Sound Level Limit} + C_1 + C_2 + C_3 + C_4$$

(i) For multiple types of noise sources (aircraft, road and rail), combine the STC values logarithmically:

$$STC_{total} = 10 \log\left( 10^{\frac{STC_1}{10}} + 10^{\frac{STC_2}{10}} + \ldots \right)$$

**The appropriate component is then chosen from the manufacturer's STC ratings of various building materials.**

| Percentage of total sound energy transmitted by this component | Correction $C_2$ |
|---|---|
| 200 | -3 |
| 160 | -2 |
| 125 | -1 |
| 100 | 0 |
| 80 | 1 |
| 63 | 2 |
| 50 | 3 |
| 40 | 4 |
| 31 | 5 |
| 25 | 6 |
| 20 | 7 |
| 16 | 8 |
| 12 | 9 |
| 10 | 10 |
| 8 | 11 |
| 6 | 12 |
| 5 | 13 |
| NOTE: The percentage of sound energy nearest to the tabulated values must be used. | |

**Table 7.8 Correction Term $C_2$ for Sound Transmission through Multiple Components (to be added to the desired Noise Reduction to obtain the required STC).**

| Component area (% of floor area) | Description of room furnishings | | |
|---|---|---|---|
| | hard | intermediate | very absorptive |
| 200 | 6 | 4 | 2 |
| 160 | 5 | 3 | 1 |
| 125 | 4 | 2 | 0 |
| 100 | 3 | 1 | -1 |
| 80 | 2 | 0 | -2 |
| 63 | 1 | -1 | -3 |
| 50 | 0 | -2 | -4 |
| 40 | -1 | -3 | -5 |
| 31 | -2 | -4 | -6 |
| 25 | -3 | -5 | -7 |
| 20 | -4 | -6 | -8 |
| 16 | -5 | -7 | -9 |
| 12 | -6 | -8 | -10 |
| 10 | -7 | -9 | -11 |
| 8 | -8 | -10 | -12 |
| 6 | -9 | -11 | -13 |
| 5 | -10 | -12 | -14 |
| NOTE: Multiple elements such as windows may be considered as one component and their combined area used as the component area. | | | |

**Table 7.9 Correction Term $C_3$ for Component Area and Room Absorption (to be added to the desired Noise Reduction to obtain the required STC).**

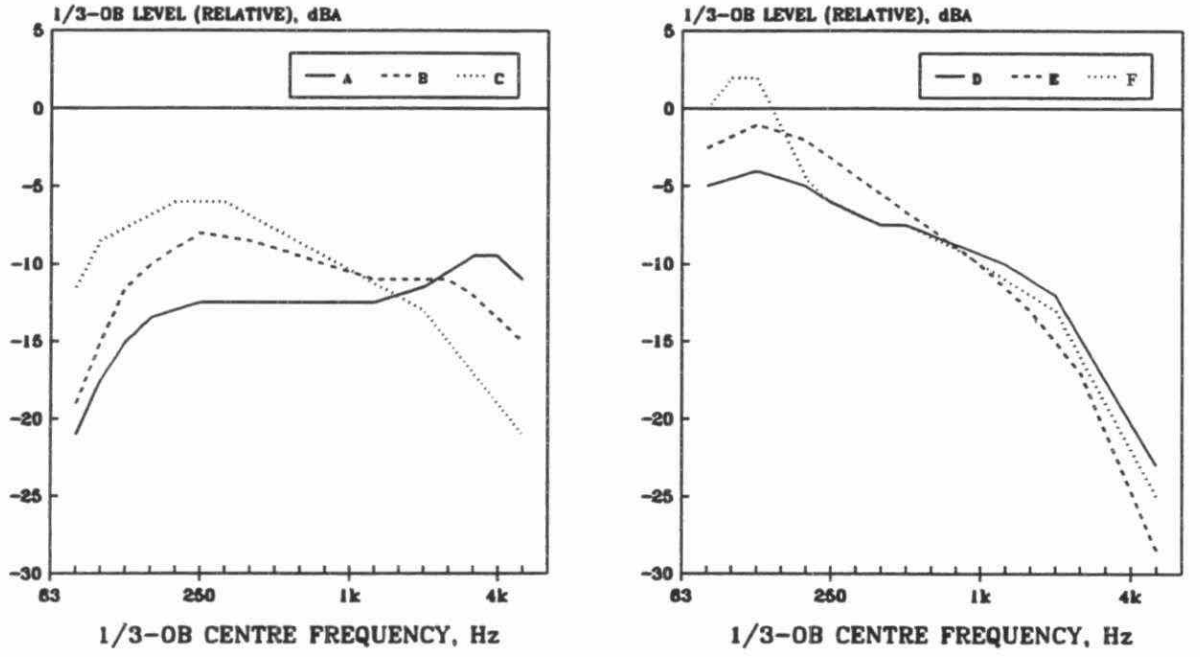



**Figure 7.5 Spectra of Common Transportation Noise**

A - LARGE AIRCRAFT LANDING
B - AVERAGE AIRCRAFT NOISE, RAILWAY WHEEL NOISE
C - RAILWAY WHEEL NOISE SCREENED BY BARRIER
D - MIXED ROAD TRAFFIC, DISTANT AIRCRAFT
E - ROAD TRAFFIC SCREENED BY BARRIER
F - DIESEL RAILWAY LOCOMOTIVE

| Building component | | Noise source spectrum | | | | | |
|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F |
| a. | Single exterior door | -1 | 0 | 0 | 1 | 1 | 1 |
| b. | Double exterior door, or single-glazed window, or openable thick window | 0 | 1 | 2 | 2 | 3 | 3 |
| c. | Sealed thin window, or openable thick window | 0 | 1 | 3 | 4 | 6 | 6 |
| d. | Sealed thick window, or exterior wall, or roof/ceiling | 0 | 2 | 5 | 7 | 9 | 10 |
| NOTE: Source spectrum categories are identified in Figure 7.5; for noise from industry or other special cases, the most similar spectrum must be used. | | | | | | | |

**Table 7.10 Correction Term $C_4$ for Frequency Dependence of the Outdoor Noise and Component Sound Transmission** (to be added to the desired Noise Reduction)

## Source: Road Traffic

**Predicted free-field night-time sound level = 68 dBA**

(Design is given for Bedroom 2 of Figure 7.4 only. Number of components is 3.)

1. Free field sound level *68* dBA
   Correction for reflections *3* dBA
   Outdoor sound level *71* dBA
   Indoor sound level *40* dBA — Subtract indoor from outdoor sound level

   Required Noise Reduction (NR) *31* dB

2. Sound comes from *0 to 90 degree* angle — $C_1$ Correction from Table 7.7 *0* dB

Sum *31* dB

---

Component: *wall* — After step 2 *31* dB

3. Transmits *33* % of total sound energy — $C_2$ from Table 7.8 *5* dB

4. Component area *4.4* $m^2$ *51* % of floor area
   Room floor area *8.6* $m^2$
   Room absorption category *intermediate* — $C_3$ from Table 7.9 *-2* dB

5. Noise spectrum type *D* (select from Fig. 7.5)
   Component category *d* (select from Table 7.10) — $C_4$ from Table 7.10 *7* dB

Required STC *41*

---

Component: *window* — After step 2 *31* dB

3. Transmits *33* % of total sound energy — $C_2$ from Table 7.8 *5* dB

4. Component area *1.6* $m^2$ *19* % of floor area
   Room floor area *8.6* $m^2$
   Room absorption category *intermediate* — $C_3$ from Table 7.9 *-6* dB

5. Noise spectrum type *D* (select from Fig. 7.5)
   Component category *c* (select from Table 7.10) — $C_4$ rom Table 7.10 *4* dB

Required STC *34*

**Worksheet 3 Evaluation of Component STC**

## Source: Road Traffic (cont.)

If a stucco wall (EW4R of Table 7.4) with STC = 55 were chosen for aesthetic reasons, the window selection may be adjusted as follows:

Component: *stucco wall* STC *55*

3. Noise spectrum type *D* (select from Fig. 5) $C_4$ from Table 7.10 *7* dB
   Component category *d* (select from Table 7.10) Correction *-7* dB

4. Component area *4.4* $m^2$ *51* % of floor area
   Room floor area *8.6* $m^2$ $C_3$ from Table 7.9 *-2* dB
   Room absorption category *intermediate* Correction *2* dB

5. Noise reduction if only this component transmits sound *50* dB

6. Required noise reduction (from Step 1) *31* dB

7. Term $C_2$: Subtract the Required NR from the Noise Reduction for this component *19* dB

8. Determine from Table 7.8 the corresponding value of total transmitted sound energy *5* %

Component: *window* After step 2 *31* dB

3. Transmits *95* % of total sound energy From Table 7.8 *0* dB

4. Component area *1.6* $m^2$ *19* % of floor area
   Room floor area *8.6* $m^2$
   Room absorption category *intermediate* From Table 7.9 *-6* dB

5. Noise spectrum type *D* (select from Fig. 5)
   Component category *c* (select from Table 7.10) From Table 7.10 *4* dB

Required STC *29*

**Worksheet 4 Reverse Evaluation of Component STC**

## 4.2 RECOMMENDED CATEGORIES OF ROOM ABSORPTION

The absorption of sound energy by different rooms depend on the type of furnishings used as well as the room floor area. Three categories of room furnishings were described in Table 7.9, namely: hard, intermediate and very absorptive.

A bedroom with thick carpets, heavy drapes and upholstered furnishings can be described as very absorptive. A typical kitchen or a bathroom is acoustically hard. Intermediate cases would include a dining room or a living room with minimal carpets.

The Ministry recommends, for evaluation purposes, the use of the following categories: bedrooms are to be treated as very absorptive, living rooms and dining rooms are intermediate cases, and kitchens and bathrooms are acoustically hard.

## 4.3 RECOMMENDED CATEGORIES OF NOISE SOURCE SPECTRA

The STC method allows for suitable correction factors to be used in order to account for the applicable sound spectra of various transportation sources; six spectra are shown in Figure 7.5 for typical transportation sources.

The Ministry recommends, for evaluation purposes, the following choice of spectra shown in Figure 7.5: spectrum type B is to be used for aircraft noise, spectrum type D is to be applied for traffic noise and spectrum type F is to be used for railway noise.

## 4.4 STC CALCULATION EXAMPLE

A worked example is given to illustrate the method. The same example from Section 3.4 is used again in this section. A sketch of the bungalow is shown in Figure 7.4. The guideline procedures are outlined in Worksheets 3 and 4.

The required STC for the wall and the window of Bedroom 2 that face the source are 41 and 34 respectively. The wall EW3 of Table 7.4 would have adequate STC. The 3 mm glass - 20 mm gap - 6 mm glass determined in the AIF calculation, chosen in Section 3.8, would provide an STC rating of about 38 if the double glazing is installed with double sash. The STC value of 38 must be reduced by 4 points if the window is openable (operable); the resultant window STC would then be 34. Consequently, the selected window (3/20/3 mm) would provide the required STC. It must be emphasized that Bedroom 2 was assumed to be of the intermediate absorptive category for comparison purposes only.

It is seen that the STC method and the AIF method produce very similar results. If the builder decides to use a wall that has more than the required STC, the insulation requirement for the window can be lowered. Such an application is shown in Worksheet 4. It is seen that by using a better wall, a standard OBC window can replace the special window chosen in Section 3.8.

## 5. COMPARISON OF AIF AND STC METHODS

Both the AIF and STC methods, presented in Sections 3 and 4, use procedures that simplify a detailed acoustical analysis. This Section presents a brief comparison of the two methods; differences in the two methods arise mainly due to the various room absorption categories (Section 4.2) and the different spectra of the transportation sources (Section 4.3).

### 5.1 AIRCRAFT NOISE

The AIF method assumes that all rooms have intermediate absorption characteristics, whereas the STC method provides three options. The AIF method uses a standard spectrum for mixed aircraft noise (spectrum type B of Figure 7.5), whereas three aircraft spectrum types are available with STC methods. If one were to consider a room of intermediate absorption characteristics and source spectrum type B, then both methods would produce similar component selection for walls, windows, doors, etc.

However, the Ministry procedure allows the bedroom to be considered as very absorptive type of interior space. Hence, the use of STC method would result in selection of slightly less stringent (in acoustic terms) walls and windows than the AIF method.

Finally, if one were to use one component with a much higher rating than required (usually a wall), the STC method provides a quick way to evaluate the necessary choices of other components associated with the wall with lower rating than the required value. A similar procedure is possible with the AIF method, but the maximum reduction in the rating is only two points.

In summary, both methods would produce similar results. However, with the application of Ministry procedures (Sections 4.2 and 4.3), the use of STC method will result in selection of a component of slightly lower rating than the AIF method. On an average, the components evaluated using the two methods would have ratings within two to three points of each other.

## 5.2 ROAD AND RAIL NOISE

Similar results to those outlined for aircraft noise are evident for road and rail noise. The AIF method uses a correction factor of +2 points (to account for source spectra of road and rail noise sources) to the basic spectrum type B of Figure 7.5 used in the evaluation. If one considered rooms of the intermediate absorption category, the resulting window selection would be similar. The major difference would be in the selection of the walls of bedrooms for rail noise. The AIF method would require a wall with a higher rating. The above major difference is of little consequence, since the Ministry procedures require a wall of the brick veneer type (EW5 of Table 7.4) irrespective of the method of evaluation.

## APPENDIX 1. LU-131: NOISE ASSESSMENT CRITERIA IN LAND USE PLANNING

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Understand the noise criteria utilized in land use planning
2. Understand the rationale for the noise criteria

Ontario

*MINISTRY OF THE ENVIRONMENT*

# Noise Assessment Criteria in Land Use Planning
# Publication LU-131

**October 1997**

*This document replaces Publication NPC-131 "Guidelines for Noise Control in Land Use Planning", of the "Model Municipal Noise Control By-Law, Final Report, August 1978".*

## PURPOSE

This guideline outlines the position of the Ministry of the Environment (MOE) on noise criteria for planning of sensitive land uses, in support of the Provincial Policy Statement under the *Planning Act* and in accordance with the Ministry of the Environment Guideline D-1 "Land Use Compatibility". It is intended for use in planning of noise sensitive land uses adjacent to facilities such as but not limited to airports, road and rail transportation corridors, industrial facilities, aggregate facilities, major commercial facilities, sewage treatment facilities, and waste sites.

In order to achieve effective and economical planning, the principles described in this document should be implemented early in the planning process. The purpose is to avoid problems in a proactive manner through input into the land use planning process. This guideline pertains to the mandate and the responsibilities of the MOE under its existing legislation, namely the Environmental Protection Act (EPA) and the Environmental Assessment Act (EAA). Other agencies, such as the federal government and municipalities, may have requirements over and above those of this MOE guideline.

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# 1. GENERAL

## 1.1 SCOPE

This Publication defines criteria for noise impact assessment of proposed residential or other noise sensitive land uses located in Class 1 and Class 2 Areas (Urban). The Publication also specifies procedures for the establishment of sound levels on the site of proposed noise sensitive land uses due to transportation sources (road, rail and air traffic) as well as stationary sources (such as industrial and commercial activities). Acceptable noise control measures are enumerated.

Responsibilities for achieving the sound level criteria that ensure a comfortable living environment are assigned. Guidance in the form of good planning criteria and procedures is provided for development of noise sensitive land uses adjacent to industrial or commercial activities.

The guidelines in this Publication are intended to assist this Ministry, and provide direction to municipalities, planning boards and consultants on the requirements of the MOE in land use planning where noise is a factor. The Publication includes an Annex, which provides additional details, definitions and rationale for the assessment criteria in the context of general planning goals and principles. Furthermore, the Annex contains supplementary noise criteria which are presented as guidance for information purposes.

## 1.2 IMPLEMENTATION

### 1.2.1 Implementation by MOE

The MOE will implement the guidelines in this document by providing comments to relevant agencies on development applications and planning documents that are circulated to the MOE under the Planning Act, as specified in Reference [15].

### 1.2.2 Municipal Implementation

This Publication is intended to assist municipalities in the preparation of official plans, official plan amendments, comprehensive zoning by-laws, rezonings, plans of subdivisions, plans of condominiums, and other applications under the Planning Act.

### 1.2.3 Technical Procedures

More specific information on the technical implementation procedures, including details of noise impact assessment methods and control measures are contained in Reference [1] and in other publications listed in Section 1.4. Reference [16] provides information regarding the use of warning clauses.

## 1.3 RESPONSIBILITY

It is the developer's responsibility to ensure that the applicable sound level criteria are met. These responsibilities include the following:

(a) determining feasibility of the project including constraints applicable before any project action is taken or construction commitment is made;
(b) assessing outdoor and indoor acoustical environments;
(c) ensuring that the required control measures are incorporated in the development.

The required control measures should be specified in an agreement with the municipality.

If the noise impact results from a stationary source, it is the developer's responsibility to investigate feasible means of impact mitigation. The preferred mitigation option is a reduction of noise emissions at the stationary source by modifying the design or the operation of the source, or by implementing noise control measures directly at the sources. In that case, a cooperative effort on the part of the developer and the stationary source owner is desirable.

The control measures that are required as a result of mitigation at the site of a stationary source should be specified in a separate agreement between the developer and the owner of the stationary source.

## 1.4 REFERENCES

Reference is made to the following publications:

[1] Noise Assessment Criteria in Land Use Planning: Requirements, Procedures and Implementation, Ontario Ministry of the Environment, May 1997.

[2] Manual for Noise Assessment in Land Use Planning, Ontario Ministry of the Environment, 1997.

[3] ORNAMENT, Ontario Road Noise Analysis Method for Environment and Transportation, Technical Document, Ontario Ministry of the Environment, ISBN 0-7729-6376, 1989.

[4] STEAM, Sound from Trains Environmental Analysis Method, Ontario Ministry of the Environment, ISBN 0-7729-6376-2, 1990.

[5] Planning Act, Government of Ontario.

[6] Environmental Protection Act, Government of Ontario.

[7] NPC-101 - Technical Definitions, part of Reference [12].

[8] NPC-102 - Instrumentation, part of Reference [12].

[9] NPC-103 - Procedures, part of Reference [12].

[10] NPC-104 - Sound Level Adjustments, part of Reference [12].

[11] NPC-205 - Sound Level Limits for Stationary Sources in Class 1 & 2 Areas (Urban).

[12] Model Municipal Noise Control By-Law, Final Report, August 1978, Ontario Ministry of the Environment.

[13] Provincial Policy Statement, Ontario Ministry of Municipal Affairs and Housing, ISBN 0-7778-6020-1, February 1, 1997.

[14] Guideline D-6, Compatibility between Industrial Facilities and Sensitive Land Uses, Ontario Ministry of the Environment, July 1995.

[15] Guideline D-1, Land Use Compatibility, Ontario Ministry of the Environment, July 1995.

[16] Bulletin No. 91003, Environmental Warnings/Restrictions, Ontario Ministry of Consumer and Commercial Relations, July 25, 1991.

## 2. DEFINITIONS

"Adverse effect"

means one or more of the following effects of sound and vibration, selected from the relevant definitions in the Environmental Protection Act, Reference [6]:

- impairment of the quality of the natural environment for any use that can be made of it;
- harm or material discomfort to any person;
- an adverse effect on the health of any person, and
- loss of enjoyment of normal use of property.

"Ambient sound level"

means Background sound level;

"Background sound level"

is the sound level that is present in the environment, produced by noise sources other than the source under impact assessment. Highly intrusive short duration noise caused by a source such as an aircraft fly-over or a train pass-by is excluded from the determination of the background sound level;

"Class 1 Area"

means an area with an acoustical environment typical of a major population centre, where the background sound level is dominated by the urban hum.

"Class 2 Area"

means an area with an acoustical environment that has qualities representative of both Class 1 and Class 3 Areas, and in which a low ambient sound level, normally occurring only between 23:00 and 07:00 hours in Class 1 Areas, will typically be realized as early as 19:00 hours.

Other characteristics which may indicate the presence of a Class 2 Area include:

- absence of urban hum between 19:00 and 23:00 hours;
- evening background sound level defined by natural environment and infrequent human activity;
- no clearly audible sound from stationary sources other than from those under impact assessment.

"Class 3 Area"

means a rural area with an acoustical environment that is dominated by natural sounds having little or no road traffic, such as the following:

- a small community with less than 1000 population;
- agricultural area;
- a rural recreational area such as a cottage or a resort area; or
- a wilderness area.

"Construction", "Conveyance"

refer to the Annex.

"Control measure"

refers to action which can be taken to achieve compatibility for the specific land use or activity. The control measure should be permanent in nature and not be readily removable or alterable by the future occupants. Control measures may include, but are not limited to, the following:

- Acoustical Barriers - berms, walls, favourable topographical features, other intervening structures;
- Architectural Design - room and corridor arrangement, blank walls, placement of windows, balconies, and courtyards, building height;

- Building Construction - acoustical treatment of walls, ceilings, selection of acoustical materials and other control devices. Provision for air conditioning;
- Mitigation at Source - noise control applied directly to the noise source;
- Site Planning - orientation of buildings and Outdoor Living Areas with respect to noise sources, spatial separation such as the insertion of noise insensitive land uses between source and receiver, appropriate setbacks, and the use of intervening service roads;
- Windows/Doors - acoustically designed windows or doors that provide the required noise reduction. In order to allow for the windows and doors to remain closed, air conditioning, i.e. mechanical ventilation and climatic control system, is necessary.

Refer to References [1] and [2] for further description of control measures and their application.

"dBA"
means the A-weighted sound pressure level.

"dBAI"
means the A-weighted sound pressure level of an impulsive sound measured with a sound level meter set to "impulse" response.

"Indoor sound level"
is an estimated sound level in the central part of a room.

"$L_{eq}(T)$: $L_{eq}(16)$, $L_{eq}(8)$, $L_{eq}(1)$"
means the A-weighted level of a steady sound carrying the same total energy in the time period T as the observed fluctuating sound. The time period T is given in hours.

"Ministry"
means the Ontario Ministry of the Environment.

"NEF/NEP"
means Noise Exposure Forecast/Noise Exposure Projection contours for major Ontario airports.

"Noise"
means unwanted sound.

"Noise sensitive land uses"
mean the following sensitive land uses:

- residential developments;
- seasonal residential developments;
- hospitals, nursing/retirement homes, schools, day-care centres, etc.

Sensitive land use means a land use that is sensitive in accordance with the definition of Reference [15], and that must be planned and/or designed using appropriate land use compatibility principles.

"Outdoor Living Area"
is the part of an outdoor area easily accessible from the building and designed for the quiet enjoyment of the outdoor environment. Outdoor Living Areas include, but are not limited to, the following:

- Backyards or front yards or gardens or terraces or patios;
- Balconies, provided they are the only Outdoor Living Areas for the occupant and meet the following conditions:

(a) minimum depth of 4 m;
(b) outside the exterior building facade;
(c) unenclosed;

- Common Outdoor Living Areas associated with multi-storey apartment buildings or condominiums;
- Passive recreational areas such as parks if identified by the municipality.

"Point of Reception"
means any point on the premises of a person where sound or vibration originating from other than those premises is received, see Reference [12].

"Stationary Source"
means a source of sound which does not normally move from place to place and includes the premises of a person as one stationary source, unless the dominant source of sound on those premises is construction or a conveyance, see Reference [12]. Section A.2.1.1 provides further explanation.

"Time Periods"
"Day-time"
is the 16-hour period between 07:00 and 23:00 hours.

"Evening"
is the 4-hour period between 19:00 and 23:00 hours.

"Night-time"
is the 8-hour period between 23:00 and 07:00 hours.

"Urban Hum"
means aggregate sound of many unidentifiable, mostly road traffic related sound sources.

"Warning Clause" (or "Environmental Warning/Restriction")
means a notification of or obligation to notify a potential purchaser of some environmental concern; in this case the concern is potential annoyance due a source of noise.

## 3. NOISE IMPACT ASSESSMENT, TRANSPORTATION SOURCES

This section deals with noise impact from transportation corridors (i.e., road, rail and air traffic). In case of multiple transportation noise sources:

(a) the outdoor noise impact due to air traffic shall be established separately from the impact due to road and/or rail traffic;
(b) the outdoor noise impact due to road and rail traffic shall be combined;
(c) the indoor noise impact shall be assessed separately for road, rail and aircraft noise. The required indoor noise control measures for the multiple source impact are then defined by a combined acoustical insulation parameter (descriptor) that is evaluated by combining the acoustical insulation parameters determined for each of the sources.

In all cases, consideration should be given to future sound levels. For road and rail noise, a minimum ten year prediction should be made and for aircraft noise, the current NEF/NEP contours shall apply.

## 3.1 ROAD AND RAIL TRAFFIC

### 3.1.1 Sound Levels

The sound levels from road and/or rail transportation at the site of a proposed noise sensitive land use shall be established using methods included in References [3] and [4]. Further details are in Section A.2 of the Annex.

### 3.1.2 Day-time Outdoor Sound Level Criterion

Table 1 gives the equivalent sound level ($L_{eq}$) criterion in the selected Outdoor Living Area. The criterion applies to the entire day-time period from 07:00 to 23:00. Section A.3.2.1 of the Annex describes the application of the criteria and the use of warning clauses.

**TABLE 1**
**Sound Level Criterion for Outdoor Living Areas**
**Road and Rail**

| Time Period | $L_{eq}$(16) (dBA) |
|---|---|
| 16 hr, 07:00 - 23:00 | 55 |

### 3.1.3 Indoor Sound Level Criteria

Table 2 gives the equivalent sound level ($L_{eq}$) criteria and the applicable time periods for the indicated types of indoor space. The specified sound level criteria are minimum requirements and apply to the indicated indoor spaces with the windows and doors closed.

**TABLE 2**
**Indoor Sound Level Criteria**
**Road and Rail**

| Type of Space | $L_{eq}$(Time Period) (dBA) | |
|---|---|---|
| | Road | Rail |
| Living/dining areas of residences, hospitals, schools, nursing/retirement homes, day-care centres, etc. (Time period: 16 hr, 07:00 - 23:00) | 45 | 40 |
| Sleeping quarters (Time period: 8 hr, 23:00 - 07:00) | 40 | 35 |

## 3.2 AIR TRAFFIC

### 3.2.1 Noise Impact

Policy 1.1.3 g) of Reference [13] establishes the applicable criterion. The noise impact on the proposed noise sensitive land use is determined based on the location of the noise sensitive land use with respect to the official Noise Exposure Forecast/Noise Exposure Projection (NEF/NEP) contours. These NEF/NEP contours are specified on a list of current contour maps available from the Ministry of Municipal Affairs and Housing. The more restrictive of the NEF and NEP contours apply. Further details are in Annex Section A.2.4 and Section A.3.2.1.

### 3.2.2 Outdoor Criterion

Table 3 gives the aircraft noise criterion in terms of an NEF/NEP value in any outdoor area, including the Outdoor Living Area. The criterion applies to the entire 24-hour period. The distance separation from the airport and, consequently, the location of the noise sensitive land use with respect to the NEF/NEP contours, is the only measure that controls the outdoor noise impact. Section A.3.2.1 of the Annex describes the application of the criterion and the use of warning clauses.

**TABLE 3**
**Outdoor Aircraft Noise Criterion**

| Time Period | NEF/NEP |
|---|---|
| 24 hours | 30 * |

* Certain conditions apply above NEF/NEP value of 25, see Section A.3.2.1. The criterion may not apply to redevelopment and infilling, see Reference [13] and Section A.3.2.1.

### 3.2.3 Indoor Criteria

Table 4 gives the indoor aircraft noise criteria in terms of NEF/NEP values for the indicated type of indoor space. These criteria apply to the entire 24-hour period. The specified criteria are minimum requirements and apply to the indicated indoor spaces with the windows and doors closed.

**TABLE 4**
**Indoor Aircraft Noise Criteria ***
**(Applicable over 24-hour period)**

| Type of Space | Indoor NEF/NEP |
|---|---|
| Living/dining areas of residences, hospitals, schools, nursing/retirement homes, day-care centres, etc. | 5 |
| Sleeping Quarters | 0 |

* The Indoor NEF/NEP values listed in Table 4 are not obtained from NEF/NEP contour maps. The values are representative of the indoor sound levels and are used as assessment criteria for the evaluation of acoustical insulation requirements, see Reference [1].

## 4. NOISE IMPACT ASSESSMENT, STATIONARY SOURCES (Industrial and Commercial Activities)

In comparison to noise from transportation sources, noise from stationary sources such as industrial or commercial activities is generally controlled more effectively at the source. If control measures are required to reduce the noise impact then these measures should be designed in accordance with the following principles:

(a) Noise from stationary sources is generally controllable at lower cost at the source than at the point of reception and, consequently, source mitigation is the preferred option;

(b) Cooperation between the developer and the owner of the stationary sources is highly desirable and often essential in order to achieve the required mitigation;

(c) Installation of noise control measures at the source will typically require a Certificate of Approval (Air), as specified in Section 9 of the Environmental Protection Act, Reference [6];

(d) Noise control measures aimed at the indoor environment, such as air conditioning, are usually immaterial because the criteria for stationary source sound levels apply to the plane of windows; the sound levels are estimated in the absence of the building. The use of central air conditioning may be acceptable under special circumstances, in certain types of developments, when the central air conditioning system forms an essential part of the overall building design - details are described in Section A.2.1.4;

(e) Assessment of noise impact produced by stationary sources typically involves calculation of sound emissions from the source, transmission and propagation of sound and the effect of intervening obstacles such as barriers. The calculation should account for the frequency characteristics of the noise source.

## 4.1 ESTABLISHMENT OF SOUND LEVELS

The sound levels anticipated on the site of a proposed noise sensitive land use shall be established in accordance with References [8], [9], [10] and [11], including all the appropriate adjustments. The assessment of noise impact shall reflect the "predictable worst case" situation, i.e. the largest difference between source sound levels and the applicable criterion.

## 4.2 FEASIBILITY ASSESSMENT

Initial assessment in the planning stage of the project is required in order to determine feasibility of development. An assessment of the hourly equivalent sound level, $L_{eq}(1)$, produced by the stationary source should be made at the property line of the proposed or committed noise sensitive land use, closest to the stationary source. The proponent of the development should demonstrate the feasibility of meeting the sound level criteria contained in Sections 4.4, 4.5 and 4.7 and, if necessary, specify the necessary noise control measures. References [1], [13] and [14] provide further information regarding feasibility studies.

Committed land use means a land use that has been approved by the regulatory authority but is not yet existing. The selected location should define the closest approach of the noise sensitive land use to the stationary source, and the location of highest noise impact.

## 4.3 CLASS 2 AREA

Aside from development in a typically Class 1 Area (urban) setting, new residential land uses may be proposed within an environment that has qualities representative of both Class 1 and Class 3 Areas. For the purposes of this document, an area having characteristics of both urban and rural environments is referred to as a Class 2 Area.

In a Class 1 Area, such as a major population centre, the background sound level is dominated by the sound of road traffic, referred to as "urban hum". In a Class 3 Area, the acoustical environment is generally made up of natural sounds typical of agricultural or wilderness areas with little or no road traffic. A Class 2 Area can be characterised by an environment generally dominated by natural sounds during the evening and night-time periods and with man made sounds during a shortened day-time period (07:00 - 19:00).

A low level "urban hum" may be audible in a Class 2 Area during the shortened day-time period (07:00 to 19:00), but would typically be absent during the evening and at night. In order to prevent adverse effects during a quieter evening background, the stationary source sound level criteria for a Class 2 Area are 5 dB more restrictive within the hours of 19:00 to 23:00.

## 4.4 OUTDOOR SOUND LEVEL CRITERIA

Table 5 gives the sound level criteria in terms of the hourly equivalent sound level, $L_{eq}(1)$, for an outdoor point of reception in any area amenable for use. The criteria should not be exceeded in any day-time hour.

**TABLE 5**
**Sound Level Criteria for an Outdoor Point of Reception**
**Stationary Sources**

| Area | Time of Day | Hourly $L_{eq}(1)$ (dBA) |
|---|---|---|
| Class 1 | 07:00 - 23:00 | 50* |
| Class 2 | 07:00 - 19:00 | 50* |
| | 19:00 - 23:00 | 45* |

* or the minimum hourly background sound level $L_{eq}(1)$, whichever is higher.

## 4.5 SOUND LEVEL CRITERIA IN THE PLANE OF A WINDOW

### 4.5.1 Day-time

Table 6 gives the day-time hourly equivalent sound level, $L_{eq}(1)$, criteria in the plane of a window. These criteria apply to the living spaces specified in Table 2. Section A.3.1.1 of the Annex describes their application.

**TABLE 6**
**Sound Level Criteria in the Plane of a Window**
**Stationary Sources**

| Area | Time of Day | Hourly $L_{eq}(1)$ (dBA) |
|---|---|---|
| Class 1 | 07:00 - 23:00 | 50* |
| Class 2 | 07:00 - 19:00 | 50* |
| | 19:00 - 23:00 | 45* |

* or the minimum hourly background sound level $L_{eq}(1)$, whichever is higher.

### 4.5.2 Night-time

Table 7 gives the night-time hourly equivalent sound level, $L_{eq}(1)$, criterion in the plane of a bedroom window. Section A.3.1.1 of the Annex describes the application of the criteria.

**TABLE 7**
**Sound Level Criterion in the Plane of a Bedroom Window**
**Stationary Sources**

| Time of Day | Hourly $L_{eq}(1)$ (dBA) |
|---|---|
| 23:00 - 07:00 | 45* |

* or the minimum hourly background sound level $L_{eq}(1)$, whichever is higher.

## 4.6 INDOOR SOUND LEVEL CRITERIA

No criteria have been established for indoor sound levels because compliance with the plane of the window criteria, Tables 6 and 7, will, in the majority of cases, ensure that the indoor sound levels are acceptable. Nevertheless, special care must be taken when assessing the impact of sound with a special characteristic such as a dominant low frequency component.

## 4.7 SPECIAL SOURCES

### 4.7.1 Specific Impulsive Sources

For impulsive sound produced by a stationary source which is a metal working operation or a gun club, or for impulses which are infrequent, the applicable sound level criteria are specified in Section 9 of Reference [11]. Sections 12 and 13 of Reference [11] also apply. Applicable times and locations are given in Tables 5, 6 and 7.

Where Reference [11] specifies two date specific criteria, depending on when the operation of the stationary source commenced, such as the 50 dBAI or 60 dBAI criteria for metal working operations, the more stringent of the criteria, i.e. 50 dBAI in the example, is applicable.

### 4.7.2 Pest Control Devices

For sound from pest control devices, the applicable sound level criteria are specified in Section 10 of Reference [11]. Sections 11, 12 and 13 of Reference [11] also apply. The applicable times and locations are given in Tables 5, 6 and 7.

### 4.7.3 Blasting

The applicable Peak Pressure Level criterion for concussion resulting from blasting operations in a mine or a quarry is 120 dB, measured in accordance with Reference [9]. The applicable Peak Particle Velocity criterion for vibration resulting from blasting operations in a mine or a quarry is 1.00 cm/s, measured in accordance with Reference [9].

### 4.7.4 Additional Guidelines

Other guidelines have been drafted or are being developed for specific stationary sources such as land fill sites, snow making equipment, and other installation/equipment.

## 5. NOISE IMPACT ASSESSMENT, MULTIPLE SOURCES

The assessment of noise impact produced by a combination of transportation noise sources is described at the beginning of Section 3.

Where a proposed noise sensitive land use is impacted by a combination of transportation and stationary sources, the noise impact from the sources should be assessed separately using the procedures in Sections 3 and 4.

The required control measures should be evaluated individually for surface transportation, aircraft and stationary sources, for day-time and night-time periods, using procedures outlined in Sections 3 and 4. The final selection of control measures should ensure the compliance with the applicable sound level criteria of this document.

October 1997

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# Annex to Publication LU-131
# Noise Assessment Criteria in Land Use Planning
**October 1997**

## A.1. BACKGROUND

### A.1.1 GENERAL

The goal of the Ontario Ministry of the Environment is to provide for the protection, conservation and wise management of the environment in Ontario and this goal is best accomplished by appropriate planning practices. The major objective of the planning process is to minimize the potential for conflict between proposed land uses and sources of pollution.

There are a number of alternatives available to ensure acceptable sound levels in communities; these range from legislation to specific methods describing how to measure, analyse and predict sound levels. Publication LU-131, Noise Assessment Criteria in Land Use Planning, contains the principles and criteria that have been established to implement the stated goal from the perspective of environmental noise. Compliance with the principles and criteria of Publication LU-131 does not provide an exemption from other relevant policies, criteria or guidelines for incompatible land uses. Publication LU-131 is supplementary to relevant policies and guidelines given in References [13], [14] and [15].

### A.1.2 PLANNING PROCESS

In the context of land use planning, the mandate of the Ministry of the Environment is derived from two legislative acts, namely the Planning Act, Reference [5] and the Environmental Protection Act, Reference [6]. The Ministry's mandate covers sound, vibration, air quality, water quality and quantity, and servicing, including water, sewage, and waste management. The Ministry of the Environment is involved in the process of planning new sources of sound, such as industrial installations, as well as in the process of planning new noise sensitive land uses, such as residential subdivisions. For new sources of sound or for changes to existing sources of sound, the Ministry issues a Certificate of Approval providing the source is in compliance with the Ministry's guidelines. For noise sensitive land uses, the Ministry makes comments and recommendations on land use planning matters related to its mandate.

The Ministry of the Environment's involvement in land use planning is part of the Ministry's preventative approach to protecting the environment. By ensuring that environmental conflicts are identified and minimized at the earliest possible stage in a development proposal, the need for subsequent abatement controls is avoided. This early planning strategy facilitates cost effectiveness and maximizes the number of available planning or design options.

### A.1.3 LEGISLATION

#### A.1.3.1 Planning Act

The Ontario Planning Act establishes the rules for land use planning in Ontario. The Act provides the basis for consideration of provincial interests related to municipal land use planning. It sets out the process for local planning administration, the preparation of municipal official plans to guide future development, the regulation of land use through zoning by-laws, the division of land into lots for sale by plan of subdivision, and the role of Ontario citizens and land owners in land use planning.

Section 3 of the Planning Act requires that, in exercising any authority that affects planning matters, planning authorities "shall have regard to" policy statements issued under the Act. The Policy Statement, Reference [13], issued under the authority of Section 3 of the Planning Act, provides direction on matters of provincial interest related to land use planning and development. Policy 1.1.3 g) of Reference [13] deals with the issues of land use compatibility and the effects of noise, and specifically states that:

> *Long term economic prosperity will be supported by planning so that major facilities (such as airports, transportation corridors, sewage treatment facilities, waste management systems, industries and aggregate activities) and sensitive land uses are appropriately designed, buffered and/or separated from each other to prevent adverse effects from odour, noise and other contaminants.*

Section A.3.2.1 deals with the aircraft noise provision of policy 1.1.3 g) of Reference [13].

### A.1.3.2 Environmental Protection Act

The Ontario Environmental Protection Act provides for the protection and conservation of the natural environment, which includes air, land and water. Under the legislation, no person shall, except under and in accordance with a valid Certificate of Approval, construct, alter, extend or replace any plant, structure, equipment, mechanism or thing that may discharge or from which may be discharged a contaminant into any part of the natural environment. In addition, no person shall discharge a contaminant or cause or permit the discharge of a contaminant into the natural environment that causes or is likely to cause an adverse effect. A contaminant for the purpose of the legislation means any solid, liquid, gas, odour, heat, sound, vibration, radiation or combination of these resulting from the human activities that may cause an adverse effect.

An adverse effect means:

(a) impairment of the quality of the natural environment for any use that can be made of it,
(b) injury or damage to property or to plant or animal life,
(c) harm or material discomfort to any person,
(d) an adverse effect on the health of any person,
(e) impairment of the safety of any person,
(f) rendering any property or plant or animal life unfit for use by man,
(g) loss of enjoyment of normal use of property, and
(h) interference with the normal conduct of business.

## A.2. IMPACT ASSESSMENT AND MITIGATION

### A.2.1 STATIONARY NOISE SOURCES

In view of the varied topographical and acoustical circumstances, the noise impact assessment of stationary sources of sound is unique, complex, and requires specialized technical calculation and/or measurement.

#### A.2.1.1 Interpretation

A stationary noise source is a source of sound which does not normally move from place to place. These types of sources are normally industrial or commercial establishments and ancillary transportation facilities. The specific noise producing equipment within these facilities include fans, blowers, generators, turbines, presses, forges, on-site trucks, bulldozers, loaders, or any combination of these or similar sources. Although some of these facilities may come under the federal jurisdiction, they have been grouped with the other stationary sources to provide consistency in the planning process.

In order to further clarify the scope of a stationary source of sound, the following list includes examples of installations, equipment, activities or facilities that are included and those that are excluded as stationary sources.

(a) Included Sources

Individual stationary sources such as:

- Heating, ventilating and air conditioning (HVAC) equipment;
- Rotating machinery;
- Impacting mechanical sources;
- Generators;
- Burners;
- Grain dryers.

Facilities, usually comprising many sources of sound. The stationary source is understood to encompass all the activities within the property boundary of the facility. The following are examples of such facilities:

- Industrial facilities;
- Commercial facilities;
- Ancillary transportation facilities;
- Aggregate extraction facilities;
- Warehousing facilities;
- Maintenance and repair facilities;
- Snow disposal sites;
- Routine loading and unloading facilities (supermarkets, assembly plants, etc.).

Other sources such as:

- Car washes;
- Race tracks;
- Firearm Ranges.

(b) Excluded Sources

Specific sources or facilities:

- Construction activities;
- Transportation corridors, i.e. roadways and railways;
- Residential air conditioning devices including air conditioners and heat pumps;
- Gas stations;
- Auditory warning devices required or authorized by law or in accordance with good safety practices;
- Occasional movement of vehicles on the property such as infrequent delivery of goods to convenience stores, fast food restaurants, etc.

Other noise sources, normally addressed in a qualitative manner in municipal noise by-laws:

- The operation of auditory signalling devices, including but not limited to the ringing of bells or gongs and the blowing of horns or sirens or whistles, or the production, reproduction or amplification of any similar sounds by electronic means;
- Noise produced by animals kept as domestic pets such as dogs barking;
- Tools and devices used by occupants for domestic purposes such as domestic power tools, radios and televisions, etc., or activities associated with domestic situations such as domestic quarrels, noisy parties, etc;
- Noise resulting from gathering of people at facilities such as restaurants and parks.

Activities related to essential service and maintenance of public facilities such as but not limited to roadways, parks and sewers, including snow removal, road cleaning, road repair and maintenance, lawn mowing and maintenance, sewage removal, garbage collection, etc.

### A.2.1.2 Assessment

The impact assessment of noise produced by stationary sources is performed either by prediction or measurement. The noise impact assessment descriptor is the one hour equivalent sound level ($L_{eq}$), and the noise impact is evaluated at a point of reception. The measured or predicted sound levels have to be adjusted for special sound characteristics such as tonality, impulsiveness and cyclic variation in order to reflect the increased annoyance to such sounds.

It should be noted that in addition to the criteria contained in Publication LU-131, the feasibility of the development is also subject to the requirements of Reference [14] that deals with separation distances between sensitive land uses such as residential developments and Class I (light), Class II (medium) and Class III (heavy) industrial facilities.

### A.2.1.3 Mitigation and Design Options

Where the noise impact exceeds the applicable criteria, mitigation is necessary. The mitigation measures may be implemented on the site of the noise sensitive land use or at the source. For stationary sources, contrary to the practice for transportation sources, the preferred and normally the most economical option is to implement noise control measures at the source, and thus reduce the noise emission. Nevertheless, an investigation should be undertaken to determine whether the measures are to be implemented at the source, receiver or both locations.

The general design principles that would allow for the juxtaposition of sensitive land uses and stationary sources can be described as follows:

- The building(s) closest to the stationary source to provide shielding for the remainder of the development;
- The building(s) closest to the stationary source to "face away" from the stationary source;
- The "exposed" side of the building(s) not to contain sensitive indoor spaces such as bedrooms and living rooms, only to include insensitive spaces such as corridors, washrooms, etc;
- No outdoor areas amenable for use on the "exposed" side of the building(s).

In the case of residential developments, single-loaded multi-unit residential buildings where the units are located on the side of the building facing away from the stationary source may present a solution.

Although it is the developer's responsibility to ensure that the applicable sound level criteria are met, a cooperative effort on the part of the developer and the stationary source owner is desirable for both parties. For the developer, cooperation will result in more economical control. For the owner of the source, there is a risk in refusing cooperation: Say the owner of the source chooses not to cooperate but the land is developed regardless and without the appropriate controls. This situation may result in complaints by the occupants of the new land use and possible action by the authorities against the owner of the source.

### A.2.1.4 Stationary Sources and Air Conditioning

Fundamentally, the use of air conditioning is an inferior and generally inappropriate means of noise mitigation. The following provides and explanation of this position:

- Air conditioning in itself is not a noise control measure. The use of air conditioning allows windows and doors to remain closed, and it is the closed windows and doors that provide the means for reducing the sound levels. Consequently, the requirement for air conditioning is in fact a requirement for closed

windows. When the windows remain closed, the indoor sound levels are acceptable but the occupants must keep the windows closed to maintain an acceptable acoustic environment.

- The use of air conditioning provides no protection for the outdoor areas and its operation often significantly increases the outdoor sound levels. In addition, this device consumes energy throughout its utilization.
- If air conditioning were to be used as a noise control measure, sensitive land uses could be placed immediately adjacent to industrial facilities (providing they are designed with protected indoor spaces). Such planning is contrary to the stated land use compatibility policies of this Ministry, which regard the juxtaposition of sensitive land uses and industrial facilities as inappropriate, Reference [14].

As a result of the above description, this Ministry does not generally accept the use of air conditioning in the context of controlling the noise from stationary sources. The exceptions to the above position, when air conditioning may be acceptable, are described below:

- Central air conditioning could be an acceptable means of mitigation in facilities such as hospitals or similar institutional uses, which are designed with air conditioning as the primary means of ventilation;
- Central air conditioning in conjunction with sealed (inoperable) windows may, in some cases, be also considered as a possible mitigation option for high-rise multiple-unit residential uses, particularly if these uses were deemed to be temporary residential uses. The appropriateness of air conditioning and sealed windows as mitigation measures in such uses would need to be assessed on an individual basis.

The use of central air conditioning as a noise mitigation measure in the above cases may or may not be acceptable. The following presents some of the factors based on which the acceptability of central air conditioning should be judged:

- sound level in the plane of a window; the higher the sound level excess above the plane of a window criteria, Sections 4.5 and 4.7, the less appropriate is the use of central air conditioning as a means of mitigation;
- potential effect on the operation of the stationary source (industry) such as possible interference with the industry's ability to obtain Certificates of Approval (Air) under Section 9 of the Environmental Protection Act; the higher the probability of affecting the operation of the stationary source (industry), the less appropriate is the use of central air conditioning as a means of mitigation;
- the type of area; a high rise development in an area which is undergoing a transition from industrial to residential is more compatible with the use of central air conditioning.

The plane of a window criteria of Sections 4.5 and 4.7 do not apply if the air conditioning is found acceptable.

When dealing with developments adjacent to transportation corridors, roads and railways, and airports, this Ministry accepts closed windows, along with a requirement for central air conditioning, as a means of mitigation. The acceptance of central air conditioning in these situations is a compromise solution, recognizing that other mitigation measures are unavailable. Also, from the land use compatibility perspective, sensitive land uses and transportation corridors are generally more compatible than sensitive land uses adjacent to industries.

### A.2.1.5 Stationary Sources and Sealed Windows

This Ministry does not generally accept the use of sealed (inoperable) windows as a noise mitigation measure. Where sealed windows are used as a result of other requirements, the Ministry shall assume that for the purpose of noise impact assessment, these windows are in fact openable (operable); exceptions to this position are described in Section A.2.1.4. The following provides a justification of this position:

- A mitigation measure must be a long term, preferably permanent, solution to the noise impact problem. As inoperable windows can be easily replaced by operable windows for a relatively low cost, this measure can only be considered as temporary.
- The land use compatibility reasoning that describes the Ministry's position with respect to the use of air conditioning is also applicable to the case of sealed windows. The use of sealed windows would

encourage development of sensitive land uses adjacent to industrial facilities and such planning is contrary to this Ministry's land use compatibility policies.

#### A.2.1.6 Predictable Worst Case Impact

The assessment of noise impact requires the determination of the "predictable worst case" impact. The "predictable worst case" impact assessment should establish the largest noise excess produced by the source over the applicable limit. The assessment should reflect a planned and predictable mode of operation based on routine activities that occur within the scope of the stationary source.

It is important to emphasize that the "predictable worst case" impact does not necessarily mean that the sound level of the source is highest; it means that the excess over the limit is largest. For example, the excess over the applicable limit at night may be larger even if the day-time sound level produced by the source is higher.

### A.2.2 ROAD TRAFFIC NOISE

The assessment of road traffic noise impact is evaluated by prediction using statistically averaged road traffic information, the higher of the AADT (Annual Average Daily Traffic) or SADT (Summer Average Daily Traffic). The prediction method for road traffic noise, recommended by this Ministry, is a method entitled ORNAMENT, Ontario Road Noise Analysis Method for Environment and Transportation, published in 1989, Reference [3], and the descriptors are the 24-hour equivalent sound level, $L_{eq}(24)$ for freeways, and the 16-hour day-time and the 8-hour night-time equivalent sound levels, $L_{eq}(16)$ and $L_{eq}(8)$, for other roads.

In order to comply with the Ministry's guidelines, the predicted noise level is to be assessed in an Outdoor Living Area, such as a rear yard or a patio, and in Indoor Living Areas, such as bedrooms and living rooms. Where the noise impact exceeds the applicable criteria, warning clauses and mitigation measures such as site planning, architectural design, noise barriers, special building components and/or central air conditioning may be necessary. No noise control measures are required if the sound level estimated in the Outdoor Living Area is 55 dBA or less during the day-time and 50 dBA or less in the plane of bedroom windows during the night-time.

### A.2.3 RAIL TRAFFIC NOISE

The assessment of rail traffic noise impact is performed using a prediction method entitled STEAM, Sound from Trains Environmental Analysis Method, published in 1990, Reference [4]. The descriptors used in the assessment are the 16-hour day-time and the 8-hour night-time equivalent sound levels, $L_{eq}(16)$ and $L_{eq}(8)$.

The impact of railway traffic noise and the requirement for control measures are assessed similarly to the road traffic noise. The noise level is to be assessed in an Outdoor Living Area, such as a rear yard or a patio, and in Indoor Living Areas, such as bedrooms and living rooms, and compared with the Ministry's guidelines. No noise control measures are required if the sound level estimated in the Outdoor Living Area is 55 dBA or less during the day-time and 50 dBA or less in the plane of bedroom windows during the night-time.

The outdoor noise impact is assessed in the Outdoor Living Area during day-time hours, 07:00 to 23:00, considering a combination of only two sources of rail traffic noise, namely the locomotive and the wheel-rail interaction. Whistle noise is not included in the outdoor noise impact assessment. The indoor noise impact is assessed in sleeping quarters during night-time hours, 23:00 to 07:00, and in living rooms or similar areas during day-time hours, 07:00 to 23:00. The assessment must consider the combination of all three railway noise sources, i.e. locomotive, wheel-rail and whistle.

The characteristic of railway noise is its high pass-by sound level for short periods and a major low frequency component produced by the operation of the diesel locomotive. This special character of the sound needs to be taken into account, particularly when assessing the indoor sound levels. Consequently, in order to account for

the special character of railway sound, the indoor sound level criteria, Table 2, are 5 dB lower than the indoor sound level criteria for road traffic noise. This difference results in a requirement for acoustically better architectural components such as windows and walls.

### A.2.4 AIRCRAFT NOISE

The Ministry assesses the impact of aircraft noise on planned noise sensitive land uses and the suitability of development. The noise impact assessment is based on the NEF/NEP contours, approved by Transport Canada.

The NEF rating is based on the Effective Perceived Noise Level (EPNL) which is given by the Perceived Noise Level (PNL), adjusted for the duration of fly-over and the presence of discrete tones. The PNL is the maximum perceived noise level calculated from the third octave band noise levels. The NEF value is then calculated from the EPNL for each fly-over, the number of fly-overs and adjustments for day-time and night-time operations. The NEP is similar to the NEF with the exception that the NEP uses a longer time frame. Neither NEF nor NEP can be measured directly and can only be calculated from measured quantities.

Where the noise impact exceeds the applicable criteria, warning clauses and mitigation measures for indoor spaces such as architectural design, special building components and/or central air conditioning are necessary. The indoor NEF/NEP values, specified in Tables 4 and A-2, are related to the actual "outdoor" values and their difference accounts for the acoustical insulation provided by the building. The indoor NEF values are calculated by converting the indoor sound levels, expressed as $L_{eq}(24)$ (dBA), using the expression NEF = $L_{eq}(24)$ - 31 dBA.

## A.3. NOISE ASSESSMENT CRITERIA

The criteria in Publication LU-131 have been designed to minimize the adverse effects of noise; they are intended to assist in the planning of land uses where noise may have a potential impact on future occupants. People's response to noise depends not only on a person's physiological reaction to the sound but on a number of other factors including the type of noise source, the character of the sound, and the community's as well as the individual's economic and social relationship to the source.

Two basic philosophies exist for establishing environmental noise criteria:

- Relative criterion, where the acceptable sound level of the source under investigation is related to (and limited by) the background sound level. The primary reference for this type of criterion is the work performed in the nineteen sixties by the National Physical Laboratory in the United Kingdom and, subsequently, the standards published by the International Organization for Standardization, ISO R-1996.[1]
- Absolute criterion, where the acceptable sound level is given by an absolute sound level limit. The primary reference for this type of criterion is the work of the United States Environmental Protection Agency, conducted in the early nineteen seventies.[2]

The foremost advantage of the relative method is that it is more directly related to human annoyance. The principal advantage of the absolute method is its simplicity of application. The relative approach is most appropriate in situations where there is an identifiable difference between the background noise and the noise of the source under investigation. In view of the fact that the background noise is generally caused by road traffic, this approach cannot be applied to establish criteria for road traffic, as there is no clear difference between the two cases. The absolute method is best applied in situations where the noise impact is caused by a "general,

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1 ISO R-1996, Assessment of Noise with Respect to Community Response, 1971.

2 US EPA, Office of Noise Abatement and Control, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, Report No. 550/9-74-004, 1974.

prevailing" noise and where a simple assessment method is required. This method provides the same "yardstick" for all situations and does not account for a variance in people's response to different noise or circumstances.

Both of the above two approaches to establishing noise criteria are correct and their suitability depends on circumstances such as the type of noise and the character of the community. Consequently, this Ministry as well as other agencies resolved to use both the relative and the absolute methods, and utilize them in conditions for which they are most suitable. In fact, the MOE has been successfully using both these methods since the late nineteen seventies. The absolute method has been adopted by this Ministry to assess the impact of road traffic and other transportation sources; the relative method has been adopted by this Ministry to assess stationary sources of sound such as industrial sources.[3]

Certain generalizations can be made about the differences in people's response to noise from stationary sources and transportation sources. People are typically more annoyed by noise from stationary sources because they perceive that practical alternatives are available to reduce or eliminate the noise at the site of the stationary source. Furthermore, tolerance of the source, which is usual for road traffic due to its general usefulness to the community, is very uncommon in the case of stationary sources of sound. The other aspects associated with the operation of stationary noise sources which contribute to adverse community reaction include the conveyance of a message of fear, a startle effect or a reminder of other adverse environmental effects.

### A.3.1 CRITERIA FOR STATIONARY NOISE SOURCES

In principle, noise produced by stationary sources is annoying when it is heard over and above the level of the "background" or surrounding environmental noise climate. The noise impact of stationary sources is therefore expressed as the difference between noise from the source and the background noise.

#### A.3.1.1 Application of Criteria

The sound level criteria for stationary noise sources in Tables 5, 6 and 7 are given in terms of minimum values, such as 50 or 45 dBA, that may be adjusted up to the level of the road traffic noise at that location. This implies that if the minimum hourly $L_{eq}(1)$ during time period in question, 19:00 to 23:00 for example, is 51 dBA, the sound level criterion becomes 51 dBA instead of 45 dBA. It should be emphasized that the noise of rail traffic and air traffic is not considered to contribute to the "background" sound level and, therefore, cannot be used to adjust the sound level criteria.

The outdoor sound level criteria, Section 4.4, apply to an outdoor point of reception at any location in any usable area. Where it can be clearly demonstrated that the area in question is not a usable area, being too small or unsuitable for use for example, the criteria need not be applied.

The plane of a window sound level criteria, Section 4.5, apply to a location in the plane of any window in living/dining areas (living rooms, dining rooms, eat-in kitchens, etc.) during day-time, and to bedrooms during night-time. The criteria need not be applied to windows in other areas such as staircases, corridors, bathrooms, closets, utility rooms, etc. In cases where central air conditioning is found as an acceptable mitigation measure, see Section A.2.1.4, the plane of a window sound level criteria do not apply.

The Ministry may in individual cases allow a certain latitude in the application of sound level criteria. However, this latitude will only be considered in cases where it can be clearly demonstrated that it is not technically feasible to achieve the criteria, and that it is not precedent setting for other cases.

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[3] The absolute method has also been adopted to assess the impact of impulsive noise produced by metal working operations, based on research performed by this Ministry; see Impulsive Noise from Forging Operations, Reaction of Some Communities in Ontario, Ontario Ministry of the Environment, 1979.

- Flexibility may be used in assessing the noise impact from a stationary source that exceeds the sound level criteria in the plane of a window, given in Tables 6 and 7 of Section 4.5. The Ministry may accept a marginal excess not exceeding 5 dB;
- In some cases, the maximum hourly sound level produced by the stationary source is lower than the long term average of the background sound level, but is higher than the lowest hourly background sound level. In addition, the operation of the stationary source is intermittent so that the potential of the maximum hourly stationary source sound level coinciding with lowest background hourly sound is very low. In such cases, the Ministry may allow a certain latitude in assessing the impact of the stationary source and accept a marginal excess over the sound level criteria;
- The Ministry may use some flexibility in assessing the impact from a stationary source that operates for only a very limited period of time within a year. For example, if the operation produces a noise impact within a period of only one or two weeks in one year, the Ministry may accept a marginal excess.

### A.3.2 CRITERIA FOR TRANSPORTATION NOISE SOURCES

The sound level criteria for transportation sources are based on sociological surveys of large numbers of people and represent what is considered to be the onset of significant degradation of the noise environment relative to the expectations of the general population. The outdoor sound level criteria represent the beginning of a significant interference with normal conversation. The indoor sound level criteria reflect potential commencement of sleep interference; they also ensure a comfortable indoor living environment.

Transportation noise in general and road traffic noise in particular is the main contributor to the environmental noise climate in Class 1 Areas. Despite the prevalence of road traffic noise in a community, people exposed to it develop a tolerance of the noise because they recognize the usefulness of this mode of transportation.

#### A.3.2.1 Application of Criteria

The transportation noise criteria apply to the development of noise sensitive land uses affected by noise produced by road, rail and aircraft traffic. Recognizing the variation of human response to transportation noise and, at the same time, the possible difficulties of implementing noise control measures in some situations, the Ministry allows a certain flexibility in the transportation sound level criteria in the Outdoor Living Areas. The application and the allowable flexibility of the criteria is described below.

In case of a marginal excess over the criteria, the prospective occupants of the new land use should be notified by means of a warning clause. This clause should be included in the Agreements of Purchase and Sale, and incorporated into the Development Agreements which are registered on title of the property.

**(a) Road and Rail**

Reference [1] provides assessment details. If the day-time sound level in the Outdoor Living Area is 55 dBA or less and the night-time level in the plane of bedroom windows is 50 dBA or less, no further assessment is required.

Where it can be clearly demonstrated that it is not technically feasible to achieve the Ministry's outdoor sound level criterion for road and rail traffic, a tolerance not more than 5 dB above the stated criteria may be allowed, providing the prospective occupants of the new land use are notified by means of a warning clause. The tolerance, and the accompanying warning clause, is only allowable in conjunction with the sound levels in the Outdoor Living Area; the tolerance is not allowable for the indoor sound level criteria.

**(b) Aircraft**

Policy 1.1.3 g) of Reference [13] states:

1. *New residential development and other sensitive land uses will not be permitted in areas near airports above 30 NEF/NEP, as set out on maps (as revised from time to time) approved by Transport Canada; but*

2. *Redevelopment of existing residential uses and other sensitive land uses or infilling of residential and other sensitive land uses may be considered above 30 NEF/NEP if it has been demonstrated that there will be no negative impacts on the long term function of the airport.*

If the outdoor NEF/NEP value is less than 25, no further assessment is required. If the proposed development is located within the NEF/NEP contour of 25, there are requirements for appropriate ventilation, acoustically designed building components and warning clauses for prospective occupants, as specified in Reference [1].

If the municipality, in accordance with Reference [13], approves the development in the NEF/NEP range above NEF/NEP 30, the noise sensitive land uses should be provided with acceptable ventilation, acoustically designed building components and warning clauses for prospective occupants, as specified in Reference [1].

## A.4. SUPPLEMENTARY NOISE CRITERIA

Criteria for noise sensitive land uses that are assessed by the Ministry are specified in the main body of Publication LU-131, Tables 2 and 4. The following Tables A-1 and A-2 are an extended version of Tables 2 and 4, and present guidelines for acceptable indoor sound levels that are applicable to developments which may not be assessed by this Ministry. The specified values are minimum requirements and apply to the indicated indoor spaces with the windows and doors closed. The criteria in Tables A-1 and A-2 are presented by this Ministry as good design objectives.

**TABLE A-1**
**Indoor Sound Level Criteria**
**Road and Rail**

| Type of Space | $L_{eq}$(Time Period) (dBA) | |
|---|---|---|
| | Road | Rail |
| General offices, reception areas, retails stores, etc. (Time period: 16 hr, 07:00 - 23:00) | 50 | 45 |
| Living/dining areas of residences, hospitals, schools, nursing/retirement homes, day-care centres, theatres, places of worship, libraries, individual or semi-private offices, conference rooms, reading rooms, etc. (Time period: 16 hr, 07:00 - 23:00) | 45 | 40 |
| Sleeping quarters of hotels/motels (Time period: 8 hr, 23:00 - 07:00) | 45 | 40 |
| Sleeping quarters of residences, hospitals, nursing/retirement homes, etc. (Time period: 8 hr, 23:00 - 07:00) | 40 | 35 |

**TABLE A-2**
**Indoor Aircraft Noise Criteria (Applicable over 24-hour period)**

| Type of Space | Indoor NEF/NEP* |
|---|---|
| General offices, reception areas, retail stores, etc. | 15 |
| Individual or semi-private offices, conference rooms, etc. | 10 |
| Living/dining areas of residences, sleeping quarters of hotels/motels, theatres, libraries, schools, day-care centres, places of worship, etc. | 5 |
| Sleeping quarters of residences, hospitals, nursing/retirement homes, etc. | 0 |

* The Indoor NEF/NEP values listed in Table A-2 are not obtained from NEF/NEP contour maps. The values are representative of the indoor sound levels and are used as assessment criteria for the evaluation of acoustical insulation requirements, see Reference [1].

## A.5. DEFINITIONS

Construction
"construction" includes erection, alteration, repair, dismantling, demolition, structural maintenance, painting, moving, land clearing, earth moving, grading, excavating, the laying of pipe and conduit whether above or below ground level, street and highway building, concreting, equipment installation and alteration and the structural installation of construction components and materials in any form or for any purpose, and includes any work in connection therewith; activities associated with the operation at waste and snow disposal sites are excluded;

Construction Equipment
"construction equipment" means any equipment or device designed and intended for use in construction, or material handling, including but not limited to, air compressors, pile drivers, pneumatic or hydraulic tools, bulldozers, tractors, excavators, trenchers, cranes, derricks, loaders, scrapers, pavers, generators, off-highway haulers or trucks, ditchers, compactors and rollers, pumps, concrete mixers, graders, or other material handling equipment;

Conveyance
"conveyance" includes a vehicle and any other device employed to transport a person or persons or goods from place to place but does not include any such device or vehicle if operated only within the premises of a person;

Highway
"highway" includes a common and public highway, street, avenue, parkway, driveway, square, place, bridge, viaduct or trestle designed and intended for, or used by, the general public for the passage of vehicles;

Motor Vehicle
"motor vehicle" includes an automobile, motorcycle, and any other vehicle propelled or driven otherwise than by muscular power, but does not include the cars of diesel, electric or steam railways, or other motor vehicles running only upon rails, or a motorized snow vehicle, traction engine, farm tractor, self-propelled implement of husbandry or road-building machine within the meaning of the Highway Traffic Act;

Motorized Conveyance
"motorized conveyance" means a conveyance propelled or driven otherwise than by muscular, gravitational or wind power.

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## APPENDIX 2. NOISE ASSESSMENT CRITERIA IN LAND USE PLANNING: REQUIREMENTS, PROCEDURES AND IMPLEMENTATION

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Understand the implementation procedures relating to noise criteria in land use planning

Ontario

*MINISTRY OF THE ENVIRONMENT*

# Noise Assessment Criteria in Land Use Planning: Requirements, Procedures and Implementation

**October 1997**

*This document provides technical details pertinent to MOE Guideline LU-131, Noise Assessment Criteria in Land Use Planning.*

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## 3. SCOPE

This document presents information relating to the details of technical assessment and review of noise impact on planned sensitive land uses. Specified are the conditions under which noise studies may be required, as well as the appropriate assessment methods and procedures. The control measures to be incorporated into the design of the development or the individual dwellings, which are required to enable compliance with the applicable noise criteria, are described as well as summarized in a tabular format.

## 4. REFERENCES

[1] LU-131, Noise Assessment Criteria in Land Use Planning

[2] ORNAMENT, Ontario Road Noise Analysis Method for Environment and Transportation, Technical Document, Ontario Ministry of the Environment, ISBN 0-7729-6376 (1989)

[3] STEAM, Sound from Trains Environmental Analysis Method, Ontario Ministry of the Environment, ISBN 0-7729-6376-2 (1990)

[4] NPC-216, Residential Air Conditioning Devices

[5] Environmental Noise Guidelines for Installation of Residential Air Conditioning Devices, Ontario Ministry of the Environment, ISBN 0-7778-1616-4 (1994)

## 3. DEFINITIONS

The majority of terms are defined in LU-131, Reference [1]. Other terminology is defined by the following:

- For the purposes of the noise impact assessment in an Outdoor Living Area, the protected area should be not less than 56 $m^2$ (600 $ft^2$) for single family dwellings, 46 $m^2$ (500 $ft^2$) for semi-detached units and 37 $m^2$ (400 $ft^2$) per unit for row housing.

- For the purposes of noise impact assessment in an Outdoor Living Area, the point of assessment is typically 3 m from the building facade and 1.5 m above ground.

- For the purposes of noise impact assessment in the plane of a bedroom window, the point of assessment is typically 4.5 m above ground unless the dwelling is a multi-storey building.

- The noise impact assessment in the Outdoor Living Area or in the plane of a window shall be performed in terms of a "free-field" sound level which is the sound level not affected by the presence of the building under assessment. The prediction methods ORNAMENT, Reference [2], and STEAM, Reference [3], yield the "free field" sound level.

## 4. NOISE IMPACT STUDIES

Feasibility or detailed noise impact studies may be required to support the development submissions. The objective of the feasibility study is to estimate the feasibility of the proposal in the context of site design and the extent of control measures such as barriers, ventilation requirements and building components. Feasibility studies should be submitted with the initial proposal.

The feasibility study should also assess the site layout including the roadways and orientation of the buildings, as well as allow for consideration of the appropriate zoning including industrial, commercial, high, low and medium density residential use. The study should alert the proponent and the approving agency of potential land use conflicts as well as determine the practicality and economic feasibility of physical noise

control measures, in conjunction with the selected site design. Furthermore, the study should provide a clear direction regarding the need for additional studies and the timing associated with the implementation of required control measures.

The purpose of the detailed study is to assess the impact of all noise sources affecting the subject lands and determine the appropriate layout, design and required control measures. The study report should include details of assessment methods, summarize the results and recommend the required outdoor as well a indoor control measures. The requirement for a detailed noise study may be a condition of initial approval of the proposed development; however, detailed studies may be prepared and submitted in place of feasibility studies.

Noise impact studies should be prepared by a qualified individual, preferably a Professional Engineer with experience in environmental acoustics.

## 4.1 AIRCRAFT NOISE

A detailed noise study is required for proposals that are located at or above NEF/NEP 25. The study should be submitted with the initial proposal. It should be noted that certain airport facilities and activities are considered as stationary sources of noise, see Section 4.3.

## 4.2 SURFACE TRANSPORTATION NOISE

### 4.2.1 Feasibility Noise Studies

Typical conditions under which a feasibility study is required are given below. The primary condition is that:

- The sound levels resulting from surface transportation noise affecting the proposed lands exceed the noise criteria by more than 10 dBA.

Alternatively, the requirement for a feasibility study may be defined in terms of a setback distance from the noise source. The following setback distances are guidelines as they may vary depending on individual site specific conditions, particularly topography.

- The proposed lands are within 100 m from a freeway right-of-way or 50 m from a provincial highway right-of-way;
- The proposed lands are within 100 m from a Principal Main Railway Line right-of-way or 50 m from a Secondary Main Railway Line right-of-way.

Irrespective of the above conditions, it is in the interest of the proponent to perform a feasibility study in the early planning stages.

### 4.2.2 Detailed Noise Studies

Typical conditions under which a detailed study is required are given below. The primary condition is that:

- The sound levels resulting from surface transportation noise affecting the proposed lands exceed the noise criteria by more than 5 dBA.

Alternatively, the requirement for a detailed study may be defined in terms of a setback distance from the noise source. The following setback distances are guidelines as they may vary depending on individual site specific conditions, particularly the presence of built-up areas or individual structures and topography.

- The proposed lands are within 500 m from a freeway right-of-way, 250 m from a provincial highway, or 100 m from the right-of-ways of other roads;
- The proposed lands are within 500 m from a Principal Main Railway Line, 250 m from a Secondary Main Railway Line, or 100 m from other railway lines.

### 4.3 NOISE FROM STATIONARY SOURCES

The category of stationary noise sources includes individual equipment and extended facilities such as industrial facilities, aggregate extraction facilities, sewage treatment facilities, ancillary transportation facilities and commercial facilities, see Annex to LU-131, Reference [1]. Feasibility as well as detailed noise studies are generally required whenever the proposed lands are within the influence area of a stationary noise source. The extent of the influence area is case specific, depending on factors such as the type and scale of the stationary source, intervening topography and intervening land uses. In general, it is in the interest of the proponent to perform a feasibility study.

## 5. ROAD NOISE CONTROL MEASURES

### 5.1 OUTDOOR LIVING AREAS

The sound level, $L_{eq}$, is determined using the ORNAMENT, Reference [2], prediction method during the daytime hours of 0700-2300. If the sound level, $L_{eq}$, in the Outdoor Living Area is less than or equal to 55 dBA, no control measures are required.

If the sound level, $L_{eq}$, in the Outdoor Living Area is greater than 55 dBA and less than or equal to 60 dBA, physical control measures may be applied to reduce the sound level to 55 dBA. If no physical measures are provided, prospective purchasers or tenants shall be informed of potential noise problems by a warning clause (Type A).

If the sound level, $L_{eq}$, in the Outdoor Living Area is greater than 60 dBA, control measures are required to reduce the level to 55 dBA. Only in cases where the required physical noise control measures are proven not to be technically, economically, or administratively feasible, such as contravening local by-laws, would an excess not greater than 5 dBA above the criterion (55 dBA) be acceptable with a warning clause Type B. When required, control measures should be designed to reduce the sound level to the criterion of 55 dBA.

#### 5.1.1 Noise Barriers

If a barrier is used as a noise control measure, its height must be such that the line of sight between the source and the receiver is obstructed. It is required that the surface density of the noise barrier be a minimum of 20 kg/m$^2$. It is further required that the barrier be designed and constructed without cracks or gaps. Any gaps under the noise barrier that are necessary for drainage purposes must be minimized and localized, and must not deteriorate the acoustical performance.

### 5.2 PLANE OF A WINDOW - VENTILATION REQUIREMENTS

The requirements are applied within two time periods.

#### 5.2.1 Night-time Period, 2300 - 0700 Hours

The sound level is determined through the ORNAMENT, Reference [2], prediction method at the plane of bedroom windows.

Control measures are not required if the $L_{eq}$ (8 hour) night-time sound level in the plane of a bedroom window is less than or equal to 50 dBA. If the sound level in the plane of a bedroom window is greater than 50 dBA and less than or equal to 60 dBA, it is required to design the dwelling with a provision for future installation of central air conditioning. This requirement usually implies forced air heating with the ducts sized for central air conditioning. Warning clause Type C is also required.

If the night-time sound level in the plane of a bedroom window is greater than 60 dBA, installation of central air conditioning is mandatory with a warning clause Type D. In addition, building components including windows, walls and doors, where applicable, must be designed so that the indoor sound levels comply with the noise criteria in Table 7. The location and installation of the outdoor air conditioning device should comply with noise criteria of NPC-216, Reference [4], and guidelines of the Environmental Noise Guidelines for Installation of Residential Air Conditioning Devices, Reference [5].

### 5.2.2 Day-time Period, 0700 - 2300 Hours

The sound level is determined through the ORNAMENT, Reference [2], prediction method at the plane of living/dining room windows.

Control measures are not required if the $L_{eq}$ (16 hour) day-time sound level in the plane of a living/dining room window is less than or equal to 55 dBA. If the sound level in the plane of a living/dining room window is greater than 55 dBA and less than or equal to 65 dBA, it is required to design the dwelling with a provision for future installation of central air conditioning. This requirement usually implies forced air heating with the ducts sized for central air conditioning. Warning clause Type C is also required.

If the day-time sound level in the plane of a living/dining room window is greater than 65 dBA, installation of central air conditioning is mandatory with a warning clause Type D. In addition, building components including windows, walls and doors, where applicable, must be designed so that the indoor sound levels comply with the noise criteria in Table 7. The location and installation of the outdoor air conditioning device should comply with noise criteria of NPC-216, Reference [4], and guidelines of the Environmental Noise Guidelines for Installation of Residential Air Conditioning Equipment, Reference [5].

## 5.3 INDOOR LIVING AREAS - BUILDING COMPONENTS

The sound level, $L_{eq}$, during the day-time (16 hour) and night-time (8 hour) periods is determined using the ORNAMENT, Reference [2], prediction method, immediately outside the dwelling envelope.

If the night-time sound level outside the bedroom windows exceeds 60 dBA or the day-time sound level outside the living/dining area windows exceeds 65 dBA, building components including windows, walls and doors, where applicable, must be designed so that the indoor sound levels comply with the noise criteria in Table 7. The acoustical performance of the building components (windows, doors and walls) must be specified.

# 6. RAIL NOISE CONTROL MEASURES

## 6.1 OUTDOOR LIVING AREAS

Whistle noise is not included in the determination of the outdoor day-time sound level. Otherwise, with the exception that the STEAM, Reference [3], prediction method is used to determine the rail traffic sound levels, all the provisions of Section 5.1 apply also to noise control requirements for rail noise.

### 6.2 PLANE OF A WINDOW - VENTILATION REQUIREMENTS

Whistle noise is not included in the determination of the sound level in the plane of a window. Otherwise, with the exception that the STEAM, Reference [3], prediction method is used to determine the rail traffic sound levels, all the provisions of Section 5.2 apply also to noise control requirements for rail noise.

### 6.3 INDOOR LIVING AREAS - BUILDING COMPONENTS

The sound level, $L_{eq}$, during the day-time (16 hour) and night-time (8 hour) periods is determined using the STEAM, Reference [3], prediction method immediately outside the dwelling envelope. Whistle noise is included in the determination of the sound level.

If the night-time sound level outside the bedroom windows exceeds 55 dBA or the day-time sound level outside the living/dining area windows exceeds 60 dBA, building components including windows, walls and doors, where applicable, must be designed so that the indoor sound levels comply with the noise criteria in Table 7. The acoustical performance of the building components (windows, doors and walls) must be specified.

In addition, the following requirement applies:

The exterior walls of the first row of dwellings next to the railway tracks shall be built to a minimum of EW5 (brick veneer) or equivalent construction from the foundation to the rafters when the rail traffic $L_{eq}$ (24 hour), estimated at a location of night time receptor, is greater than 60 dBA and when the first row of dwellings are within 100 m of the tracks.

Note: EW5 is an exterior wall composed of 12.7 mm gypsum board, vapour barrier and 38 x 89 mm studs with 50 mm (or thicker) mineral wool or glass fibre batts in inter-stud cavities plus sheathing, 25 mm air space and 100 mm brick veneer.

## 7. COMBINATION OF ROAD AND RAIL NOISE

The noise impact in the OLA and in the plane of a window, and the requirements for outdoor measures, ventilation measures and warning clauses, shall be determined by combining road and rail traffic sound levels.

The assessment of the indoor sound levels and the resultant requirement for the acoustical descriptors, AIF or STC, of the building components shall be performed separately for road and rail noise. The resultant acoustical descriptors, AIF or STC, shall subsequently be combined to determine the required components.

## 8. AIRCRAFT NOISE CONTROL MEASURES

The noise impact from aircraft is assessed using the NEF/NEP contour maps. The NEF/NEP contour values are approved by Transport Canada for various airports in Canada.

If the receptor location is within the NEF/NEP contours of 25 and 30, it is required to design the dwelling with a provision for central air conditioning. This requirement usually implies forced air heating with the ducts sized for future installation of central air conditioning. In addition, building components including windows, doors, walls and ceiling/roof must be designed to achieve the indoor sound level criteria. Warning clause C is also required.

If the receptor location is within the NEF/NEP contours of 30 and 35, central air conditioning is mandatory with a warning clauses Type B and D. In addition, building components including windows, doors, walls and ceiling/roof must be designed to achieve the indoor sound level criteria.

## 9. COMBINATION OF ROAD, RAIL AND AIRCRAFT NOISE

The noise impact in the OLA and in the plane of a window, and the requirements for outdoor measures, ventilation measures and warning clauses, shall be determined separately for surface transportation and aircraft noise. Surface transportation impact shall be performed by combining road and rail traffic sound levels.

The assessment of the indoor sound levels, and the requirements for the acoustical performance of building components, shall be performed separately for road noise, rail noise and aircraft noise. The resultant acoustical descriptors, such as AIF or STC, shall be subsequently combined to determine the overall acoustical descriptor. Selection of the required components shall be based on the overall descriptor.

## 10. CONTROL MEASURES FOR STATIONARY SOURCES

The assessment of noise impact produced by stationary sources and any resultant control measures is more complex than that of transportation sources. The following is a brief and simplified summary of the requirements. Annex to Publication LU-131, Reference [1], provides additional details.

The sound level, $L_{eq}$ (1 hour), at a point of reception is determined during day-time and night-time hours either through prediction methods or from measurements. If the sound level in any given hour exceeds the applicable criteria, summarized in Table 7, control measures are required.

When control measures are required, they are expected to reduce the sound level to the applicable criteria at all the points of reception within the proposed development. The noise impact may be controlled at the source or at the receptor; typically, the available control measures consist of noise barriers, erected on the property of the sensitive land use, or "at-the-source" control measures such as silencers, mufflers or enclosures. Preferably, the control should be implemented at the source in order to reduce the noise emissions.

Warning clauses that are used in place of physical control measures to identify an excess over the Ministry criteria are not acceptable. Warning clause (Type E) for stationary sources may identify a potential concern due to the juxtaposition of the facility but must not be utilized to justify an excess over the criteria.

## 11. STATIONARY AND TRANSPORTATION SOURCES

The required control measures for transportation and stationary sources should be evaluated separately for day-time and night-time periods. The final selection of control measures should ensure the compliance with the applicable sound level criteria of this document.

## 12. CENTRAL AIR CONDITIONING

Central air conditioning is required in order to ensure that the windows may remain closed. The ventilation system must provide temperature and humidity control and must not generate sound levels that exceed the applicable indoor sound level criteria.

In the majority of situations, particularly for single family dwellings, central air conditioning is the only ventilation system that satisfies the above conditions. However, in high and medium density residential developments, other forms of mechanical ventilation may be available. Ventilation methods other than central air conditioning are acceptable for high and medium density residential developments, subject to the following conditions:

(a) the noise produced by the proposed ventilation system complies with the indoor noise criteria of Table 7. In practice, this condition usually implies that window air conditioning units are not acceptable;

(b) the ventilation system complies with all national, provincial or municipal standards and codes;

(c) the ventilation system is designed by a Professional Engineer expert in heating and ventilation;

(d) the ventilation system enables the windows and exterior doors to remain closed.

## 13. PROVISION FOR CENTRAL AIR CONDITIONING

Provision for central air conditioning is required in order to allow central air conditioning to be installed in the future, and enable windows to remain closed.

In the majority of situations, particularly for single family dwellings, provision for central air conditioning implies forced air heating with the ducts sized for the future installation of central air conditioning. However, in high and medium density residential developments, other forms of heating and mechanical ventilation may be available Ventilation methods other than forced air heating and central conditioning are acceptable for high and medium density residential developments, subject to the conditions outlined in Section 12. The main condition is that the noise produced by the proposed ventilation system complies with the indoor noise criteria of Table 7. In practice, this condition implies that window air conditioning units are not acceptable.

## 14. WARNING CLAUSES

### 14.1 TRANSPORTATION SOURCES

The following warning clauses may be used individually or in combination:

TYPE A:

"Purchasers/tenants are advised that sound levels due to increasing road (rail) (air) traffic may occasionally interfere with some activities of the dwelling occupants as the sound levels exceed the Municipality's and the Ministry of the Environment's noise criteria."

TYPE B:

"Purchasers/tenants are advised that despite the inclusion of noise control features in the development and within the building units, sound levels due to increasing road (rail) (air) traffic may on occasions interfere with some activities of the dwelling occupants as the sound levels exceed the Municipality's and the Ministry of the Environment's noise criteria."

TYPE C:

"This dwelling unit has been fitted with a forced air heating system and the ducting, etc. was sized to accommodate central air conditioning. Installation of central air conditioning by the occupant will allow windows and exterior doors to remain closed, thereby ensuring that the indoor sound levels are within the Municipality's and the Ministry of the Environment's noise criteria. (Note: The location and installation of the outdoor air conditioning device should be done so as to comply with noise criteria of MOE Publication NPC-216, Residential Air Conditioning Devices and thus minimize the noise impacts both on and in the immediate vicinity of the subject property.)"

TYPE D:

"This dwelling unit has been supplied with a central air conditioning system which will allow windows and exterior doors to remain closed, thereby ensuring that the indoor sound levels are within the Municipality's and the Ministry of the Environment's noise criteria."

### 14.2 STATIONARY SOURCES

TYPE E:

"Purchasers are advised that due to the proximity of the adjacent industry (facility) (utility), sound levels from the industry (facility) (utility) may at times be audible."

## 15. VERIFICATION OF NOISE CONTROL MEASURES

Implementation of noise control measures should be verified (certified) by a qualified individual, preferably a Professional Engineer with experience in environmental acoustics.

## 16. SUMMARY OF MINIMUM NOISE CONTROL AND VENTILATION REQUIREMENTS FOR ROAD, RAIL AND AIRCRAFT NOISE

**TABLE 1**
**COMBINATION OF ROAD AND RAIL NOISE, DAY-TIME (0700 - 2300)**
**OUTDOOR, VENTILATION AND WARNING CLAUSE REQUIREMENTS**

| ASSESSMENT LOCATION | $L_{eq}$ (16 hr) (dBA) | VENTILATION REQUIREMENTS | OUTDOOR CONTROL MEASURES | WARNING CLAUSE |
|---|---|---|---|---|
| OUTDOOR LIVING AREA (OLA) | Less than or equal to 55 dBA | N/A | None required | Not required |
| | Greater than 55 dBA to less than or equal to 60 dBA | N/A | Control measures (barriers) not required but should be considered | Required if resultant $L_{eq}$ exceeds 55 dBA Type A |
| | Greater than 60 dBA | N/A | Control measures (barriers) required to reduce the $L_{eq}$ to below 60 dBA and as close to 55 dBA as technically, economically and administratively feasible | Required if resultant $L_{eq}$ exceeds 55 dBA Type B |
| PLANE OF LIVING ROOM WINDOW | Greater than 50 dBA to less than or equal to 55 dBA | None required | N/A | Not required |
| | Greater than 55 dBA to less than or equal to 65 dBA | Forced air heating with provision for central air conditioning | N/A | Required Type C |
| | Greater than 65 dBA | Central air conditioning | N/A | Required Type D |

**TABLE 2**
**COMBINATION OF ROAD AND RAIL NOISE, NIGHT-TIME (2300 - 0700)**
**VENTILATION AND WARNING CLAUSE REQUIREMENTS**

| ASSESSMENT LOCATION | $L_{eq}$ (8 hr) (dBA) | VENTILATION REQUIREMENTS | WARNING CLAUSE |
|---|---|---|---|
| PLANE OF BEDROOM WINDOW | Greater than 50 dBA to less or equal to 60 dBA | Forced air heating with provision for central air conditioning | Required Type C |
| | Greater than 60 dBA | Central air conditioning | Required Type D |

**TABLE 3**
**ROAD AND RAIL NOISE, DAY-TIME (0700 - 2300)**
**BUILDING COMPONENT REQUIREMENTS**

| ASSESSMENT LOCATION | | $L_{eq}$ (16 hr) | BUILDING COMPONENT REQUIREMENTS |
|---|---|---|---|
| PLANE OF LIVING ROOM WINDOW | ROAD | Less than or equal to 65 dBA | Building compliant with the Ontario Building Code |
| | | Greater than 65 dBA | Building components (walls, windows, etc.) must be designed to achieve indoor sound level criteria |
| | RAIL | Less than or equal to 60 dBA | Building compliant with the Ontario Building Code |
| | | Greater than 60 dBA | Building components (walls, windows, etc.) must be designed to achieve indoor sound level criteria |

**TABLE 4**
**ROAD AND RAIL NOISE, NIGHT-TIME (2300 - 0700)**
**BUILDING COMPONENT REQUIREMENTS**

| ASSESSMENT LOCATION | | $L_{eq}$ (8 hr) | BUILDING COMPONENT REQUIREMENTS |
|---|---|---|---|
| PLANE OF BEDROOM WINDOW | ROAD | Less than or equal to 60 dBA | Building compliant with the Ontario Building Code |
| | | Greater than 60 dBA | Building components (walls, windows, etc.) must be designed to achieve indoor sound level criteria |
| | RAIL | Less than or equal to 55 dBA | Building compliant with the Ontario Building Code |
| | | Greater than 55 dBA | Building components (walls, windows, etc.) must be designed to achieve indoor sound level criteria |

**TABLE 5**
**AIRCRAFT NOISE - 24 HOURS**

| ASSESSMENT LOCATION | NEF OR NEP | VENTILATION REQUIREMENTS | NOISE CONTROL REQUIREMENTS | WARNING CLAUSE |
|---|---|---|---|---|
| ANY LOCATION ON PROPERTY OR LOT | Less than NEF 25 | None required | Building compliant with the Ontario Building Code | Not required |
| | Greater or equal to NEF 25 to less than NEF 30 | Provision for central air conditioning | Building components (walls, windows, etc.) must be designed to achieve indoor sound level criteria | Required Type C |
| | Greater than NEF 30 | Central air conditioning | Building components (walls, windows, etc.) must be designed to achieve indoor sound level criteria | Required Type B and D |

**TABLE 6**
**FACADE REQUIREMENT FOR RAIL NOISE ONLY - 24 HOURS**

| ASSESSMENT LOCATION | DISTANCE TO RAILWAY (m) | $L_{eq}$ (24 hr) (dBA) | NOISE CONTROL REQUIREMENT |
|---|---|---|---|
| PLANE OF BEDROOM WINDOW | Less than 100 m | Less than or equal to 60 dBA | No additional requirement |
| | | Greater than 60 dBA | Brick veneer or acoustically equivalent |
| | Greater than 100 m | Less than or equal to 60 dBA | No additional requirement |
| | | Greater than 60 dBA | No additional requirement |

## 17. LU-131 NOISE CRITERIA SUMMARY

**TABLE 7**
**SUMMARY OF NOISE CRITERIA FOR SENSITIVE DEVELOPMENTS**

| Receiver Category | | Time Period | Source Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Road Traffic | | Rail Traffic | | Aircraft | | Stationary | |
| | | | Criterion Averaged over Time Period | | Criterion Averaged over Time Period | | Criterion Averaged over 24 Hours | | Criterion Averaged over any Hour during Time Period | |
| | | | $L_{eq}$ | Applies | $L_{eq}$ | Applies at | NEF | Applies at | $L_{eq}$ | Applies at |
| Outdoor | Class 1 | 0700-2300 | 55[1] | OLA | 55[1,4] | OLA | 30[2] | ANYWHERE ON PROPERTY | 50[3] | OPOR |
| | | 2300-0700 | - | | - | | | | - | |
| | Class 2 | 0700-1900 | 55[1] (16 hr) | OLA | 55[1,4] (16 hr) | OLA | 30[2] | ANYWHERE ON PROPERTY | 50[3] | OPOR |
| | | 1900-2300 | | | | | | | 45[3] | OPOR |
| | | 2300-0700 | - | | - | | | | - | |
| Plane of Window | Class 1 | 0700-2300 | - | | - | | - | | 50[3] | POW |
| | | 2300-0700 | - | | - | | | | 45[3] | POW |
| | Class 2 | 0700-1900 | - | | - | | - | | 50[3] | POW |
| | | 1900-2300 | | | | | | | 45[3] | POW |
| | | 2300-0700 | - | | - | | | | 45[3] | POW |
| Indoor[6] | Class 1 & 2 | 0700-2300 | 45 | Living Quarters | 40[5] | Living Quarters | 5 | Living Quarters | -[7] | Living Quarters |
| | | 2300-0700 | 40 | Sleeping Quarters | 35[5] | Sleeping Quarters | 0 | Sleeping Quarters | -[7] | Sleeping Quarters |

NOTES:

1 The criterion may be exceeded by an amount not greater than 5 dBA, subject to justification and use of a Warning Clause.

2 Redevelopment of existing residential uses and other sensitive land uses or infilling of residential and other sensitive land uses may be considered above 30 NEF/NEP if it has been demonstrated that there will be no negative impacts on the long term function of the airport. This is subject to implementation of appropriate control measures including a Warning Clause.

3 or Hourly $L_{eq}$ of road traffic, whichever is higher.

[4] Whistle noise excluded.

[5] Whistle noise included.

[6] Other guidelines for offices, hotels, places of worship, stores, etc. are contained in Annex to LU-131, Reference [1].

[7] Compliance with the plane-of-window criteria should ensure that the indoor sound levels are acceptable. Special care must be exercised with some sources.

DEFINITIONS:

**OLA** means Outdoor Living Area

**POW** means Plane of Window

**OPOR** means Outdoor Point of Reception

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## APPENDIX 3. MEASUREMENT OF SOUND

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Outline the significance of the sound level meter.
2. Outline the applications of various sound level meters.
3. Describe the principles and functioning of sound level meters.
4. Explain the significance of types 1, 2 and 3 sound level meters.
5. Identify limitations of sound level meters while measuring different types of noise sources.
6. Identify why calibration of sound level meters is important. Describe how calibration is done and when.

## MEASUREMENT OF SOUND

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# MEASUREMENT OF SOUND

## 1. INTRODUCTION

In order to quantitatively assess the magnitude of noise impact, it is necessary to measure the sound pressure level. This can be accomplished using a sound level meter which is an instrument consisting of a microphone, an amplifier, weighting filters, and an indicating meter. The microphone converts sound waves into corresponding electric signals which is then amplified and modified in such a way as to provide readings of sound pressure level on the indicating meter. Usually, a control, also called an attenuator, is provided to adjust the range of sound levels that can be read, permitting the meter to be used for measurements over wide range of sound levels.

The electronic filters, such as A and frequency band, are incorporated in the sound level meter to assess the effect of noise on people. Usually, the A-weighting is used as its response characteristics corresponds most closely to the response of the ear to most types of environmental sounds. Some sound level meters are also equipped with one-octave or one-third octave-band filters to conduct spectrum analysis of the measured sound.

Sound level meters commonly measure the averaged level of the acoustical signal, and the response of the indicating meter is determined by pre-selection of one of the meter time weighting characteristics, "Slow" or "Fast". These characteristics determine the time over which the signal is integrated to provide an averaged reading.

One of the primary differences between various sound level meters is accuracy. Technical standards specify four types of sound level meters:

Type 0 - Precision Sound Level Meter - used only for noise and vibration measurements in scientific research and development as well as for noise emission certification.

Type 1 - Precision Sound Level meter - used only in carefully controlled field environments or in laboratory work.

Type 2 - General Purpose Sound Level Meter

Type 3 - Survey Sound Level Meter - rarely used except as a quick check on noise levels.

There is a great variety of instruments available on the market, and a wide variety of applications to which they may be put. The use of Type 0 and Type 3 sound level meters is not recommended by this Ministry.

## 2. REVIEW OF ENVIRONMENTAL NOISE INSTRUMENTATION

### 2.1 GENERAL PURPOSE SOUND LEVEL METERS

Type 2 meters usually use piezoelectric microphones and have an accuracy of at least ±2 dB at 1 kHz. They usually incorporate the A, B and C weighting filters, and allow measurements over a wide range of sound levels. Octave-band filters and detachable microphones may also be incorporated.

### 2.2 PRECISION SOUND LEVEL METERS

In general, these meters are used only in carefully controlled field environment or in laboratory work. They have accurate microphones of either the air- or electret-condenser type which may be mounted remotely in order to minimize the effect of the operator and instrument case on the incident sound field. These meters can measure over a larger range of sound levels than the general purpose meters and have an accuracy of at least ±1 dB at 1 kHz.

In addition to "Slow" and "Fast", they may also be equipped with "Impulse" and "Peak" time-weighting characteristics, which enable measurement of impulse noise such as forging, stamping or gun fire.

### 2.3 INTEGRATING SOUND LEVEL METERS FOR LEQ MEASUREMENTS

As described earlier in this Chapter, the conventional sound level meters average (integrate) the acoustic signal. The averaging time is selected by the "Slow", "Fast", "Impulse", "Peak", time-weighting characteristics incorporated in the meter.

The integrating sound level meter simply carries the averaging idea a step further by providing a much wider choice of averaging times. Instead of being limited to a maximum averaging time constant of one second (using "Slow" time-weighting characteristic of the meter), an integrating sound level meter may be capable of averaging over many minutes, hours and even days.

Another difference between the conventional and integrating sound level meters is that the latter gives the same weight to all the earliest and latest (and all - in between) parts of the acoustical signal, while a conventional sound level meter gives greater weight to the more recently occurring part of the sound signal then to the older parts (exponential). It is important to remember the following rules:

- If a sound is constant in level, conventional and integrating sound level meters will give identical results.

- If a sound signal fluctuates in level, the conventional sound level meter reading will fluctuate while the integrating sound level meter will average the fluctuations and produce an averaged reading.

Although a conventional sound level meter can be used to measure long-time average level, the operator must sample and record many sound level readings while making certain that in this sampling process, a significant noise event is not missed. Then, he must carry out manually the calculations of the average. The integrating sound level meter performs the measurement (integrating samples of sound signal) automatically, improving accuracy and reducing the possibility of measurement error.

Commercially available integrating sound level meters are usually capable of measuring Leq, maximum sound level and integration time (or elapsed time).

The integration time can be preset for automatic operation or controlled manually, and a pause control is provided to permit inhibition of unwanted noise events. Full facility instruments are capable of making ordinary sound level measurements using various frequency filters and detector characteristics (i.e. "Slow", "Fast", "Impulse", "Peak"). They may also be able to operate with plotters, printers and other output devices.

### 2.4 ACOUSTIC CALIBRATORS

In order to obtain reliable results of noise measurements, calibration checks of the sound level are required for each measurement taken. This may be achieved by the use of a calibrator, an accurate sound source which introduces a reference sound level signal into the microphone. The procedure involves placing the calibrator over the microphone and adjusting the sound level meter until the meter reading corresponds to the reference sound pressure level. This calibration must be performed on location immediately before and after measurement.

**See NPC-102 for a complete description of instrumentation, their uses and calibration.**

## 3. MEASUREMENT TECHNIQUES

NPC-103 comprises the various measurement procedures to be used. Factors included are:

1) Classification of the type of sound
2) The type of sound level meter appropriate for the type of sound

3) Measurement location
4) Calibration
5) Measurement procedures including duration, readings reported, how to deal with variations, effect of weather conditions, effect of local structures
6) Reporting procedures: appropriate descriptions of the acoustical environment, instrumentation, and presentation of data

When performing acoustical measurements, consideration must be given to the use of the sound level meter and to the relationship between the instrument and the noise source. Improper use of the meter will affect the accuracy of acoustical measurements.

It is essential to operate a sound level meter in a manner that will not alter the sound field being measured. The effect of background noise and meteorological conditions must be taken into account in order to obtain reliable measurement results. The following is a more detailed discussion of these effects:

## 3.1 THE EFFECT OF REFLECTING SURFACES

When measuring outdoor noise sources, the presence of walls, obstructions and even the operator, can affect the sound field of the source. This disturbance can cause incorrect measurements. The errors are most marked in the frequency range of 200-4000 Hz, when the physical dimensions of objects are similar to, or larger than, the wavelength of the sound.

The most effective way to avoid these errors is to select measurement sites which are far-removed from any reflecting surfaces. The meter should be held (or positioned on the tripod) away from the operator's body to prevent sound reflections. Also the operator must not be located between the meter and the noise source. In order to reduce errors due to the presence of the operator, the sound level meter may be attached to the pistol clip and held at arm's length during the measurements.

## 3.2 THE EFFECT OF MICROPHONE ORIENTATION

There are two types of microphones used in sound measurements. The first type of microphone should be pointed towards the sound source if the sound field is estimated to be coming from one direction. This is known as a free field response type.

Some microphones are designed to be pointed at right angles to the source (grazing incidence). These microphones are known as random-incidence response types.

## 3.3 THE EFFECT OF BACKGROUND NOISE

Background noise will cause errors when taking acoustical measurements whenever it is within 10 dB of the noise being measured. If the sound pressure level generated by noise source under measurement is 10 dB or greater than the background sound pressure level alone then the background noise has virtually no effect. The result of this measurement is essentially the sound pressure level generated by the noise source. However, if the sound pressure level measured in the vicinity of a ventilating fan is 66 dBA, and the background level at the same location, with the fan shut off, is 57 dBA or higher, the result of fan noise measurement will not be reliable. In such a situation, it is best to reschedule the measurements until the background level on the site drops to below 55 dBA.

## 3.4 EFFECT OF METEOROLOGICAL CONDITIONS

Outdoor noise measurements should not be performed under excessively windy conditions, and if the humidity and temperature are outside the range specified by the manufacturer of the measuring instrumentation.

The following limitations generally apply:

(a) wind speed in excess of 15 km/h;
(b) temperature, outside the range -10°C to 50°C;
(c) relative humidity in excess of 90%.

High wind speeds generate turbulence around the microphone which causes pressure fluctuations which the microphone senses as sound. This "pseudo-sound" is often of sufficiently high level to mask the actual noise under investigation.

High wind speeds also create sounds in the environment which are not otherwise present, such as rustling, creaking, whistling, howling, etc.

Also, sound measurements should not be attempted under conditions of temperature beyond the meter specifications. The temperature range of operation of the meter is usually quoted in the instruction manual. High humidity conditions can cause measurement errors. Most meters are not to be used if the humidity exceeds 90%. If condenser microphones are being used, moisture can condense between the diaphragm and back plate making measurements unreliable.

In addition to the above limitations, it is a good practice to note the wind direction as the propagation of sound in air can be strongly affected by wind, especially close to the ground surface.

## 3.5 PROPAGATION

Atmospheric conditions may have significant effect on the level of noise produced by a distant source. This effect may be illustrated using sound rays, shown in Figure 3.1. Atmospheric conditions affect the speed of sound at various altitudes and directions which are drawn at right angles to the sound wave-front. A "normal" atmosphere where the sound level steadily in all directions is shown in Figure 3.1 (a).

Figure 3.1 (b) shows how a temperature inversion can reflect the rays back towards the ground surface and, as a result, increase the sound level. Figure 3.1 (c) shows the most commonly found effect, that of wind. The sound ray is bent in the direction in which the wind is blowing, resulting in an increased sound pressure level downwind and reduced sound pressure level upwind. If both temperature inversion and wind are present, a condition could exist as illustrated in Figure 3.1 (d) where focussing of the rays occurs downwind.

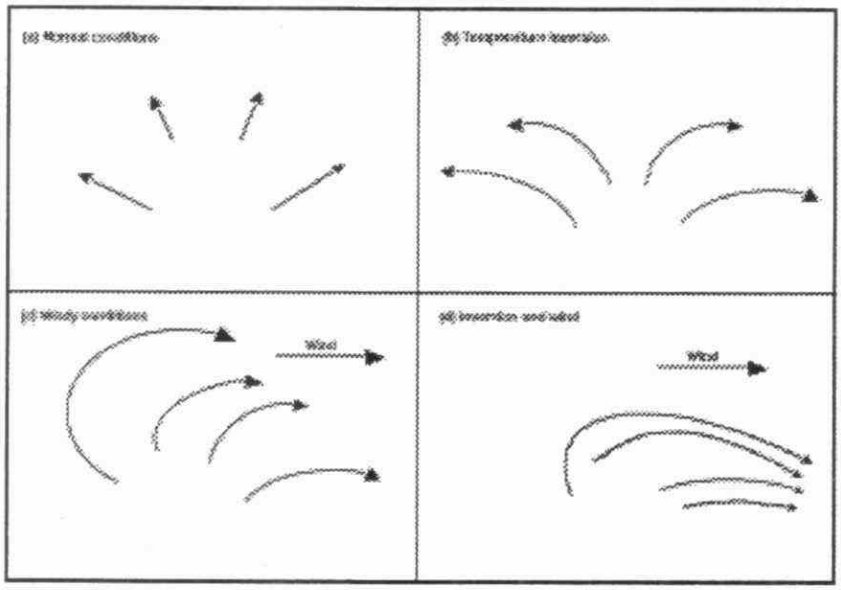

**Figure 3.1 Sound Propagation**

## APPENDIX 4. VIBRATION

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Understand the nature of vibration
2. Understand how to evaluate vibration impacts
3. Describe basic vibration instrumentation

# VIBRATION

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# VIBRATION

## 1. INTRODUCTION

The mathematical and physical descriptions of vibration are similar to those of sound even though the control measures are very different. This chapter presents a brief description of the fundamentals of vibration and its behaviour, along the same lines as that of sound which is given in the chapter dealing with acoustics. A few of the important sources of vibration are outlined and available procedures for impact assessment are also presented.

## 2. NATURE OF VIBRATION

### 2.1 GENERAL DESCRIPTION

Vibration is the movement of particles in time and space. Descriptors of vibration are displacement, velocity or acceleration in a solid medium. Any moving disturbance produces vibration. Unlike sound, vibration requires the presence of solid medium for its existence, transmission and perception. In contrast, sound may be described as audible vibrations of air. Some examples of vibrating sources are punch presses, a moving train and any rotating machinery.

Vibration travels in the form of waves from the source to the receiver just like sound. Due to the characteristics of solid medium, vibration travels both as a longitudinal wave as well as a transverse wave, unlike sound which propagates only as a longitudinal wave. One other major difference between vibration and sound is that sound pressure is a scalar quantity whereas vibration is a vector quantity, and hence the direction of the vibration vector is a required quantity when reporting the vibration results.

### 2.2 PHYSICAL DESCRIPTION OF VIBRATION

Vibration is usually generated by physical motion such as heavy footsteps on a long span floor or rotating machinery with a slight imbalance. The reactive motion represents the physical measure of the vibration excitation. Motion is generally described in terms of displacement, velocity (rate of change of displacement) or acceleration (rate of change of velocity). Unlike sound where sound pressure is a meaningful single physical measure, vibration can be described in terms of any of the above three measures. Each one of the three is a valid measure depending on the specific vibration environment. The three measures are closely related to each other. Velocity is the time rate change of displacement and acceleration is the time rate change of velocity. The above relationships are graphically described in Figure 4.1. Logarithmic scale is used for relative level and frequency.

### 2.2.1 Vibration Descriptor

In theory, it is irrelevant which of the three parameters, acceleration, velocity or displacement are chosen to measure vibration. Displacement measurements give low frequency components most weight and conversely acceleration measurements give more weight to the high frequency components. This leads to a practical consideration that can influence the choice of parameter. It is advantageous to select the parameter which gives the flattest frequency spectrum in order to best utilize the dynamic range of the measuring instrumentation.

Due to the nature of mechanical systems appreciable displacements only occur at low frequencies, therefore, displacement measurements are of limited value in the general study of mechanical vibrations. Displacement is often used as an indicator of unbalance in rotating machine parts because relatively large displacements usually occur at the shaft rotation frequency, which is the frequency of primary interest for balancing purposes. Displacement is also used to measure seismic vibration as they occur at low frequencies.

Velocity measurements are widely used for vibration "severity" measurements. This is due to the fact that vibratory velocity is simply related to vibratory energy and is, therefore, a measure of the destructive effect of vibration. A given velocity level also signifies constant stress for geometrically similar constructions vibrating in the same mode.

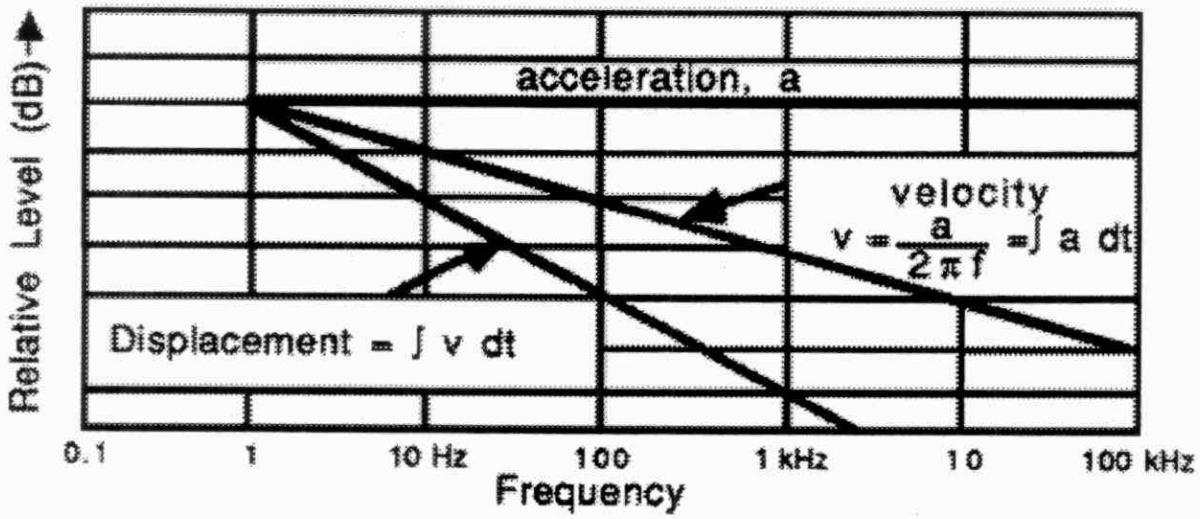


**Figure 4.1 Integration and Double Integration of Acceleration to Obtain Velocity and Displacement.**

Because acceleration measurements are weighted towards high frequency vibration components, this parameter is preferred where the frequency range of interest covers high frequencies.

## 2.3 VIBRATION PROPAGATION

The propagation of sound was described using simple spherical or cylindrical waves as related to point sources and line sources. Vibration also travels in the form of waves. However, propagation of vibration is a complex phenomenon (even in land use assessment) depending on the source type, the solid medium through which vibration is being transmitted and the coupling between the two. The different vibration wave types travel at different wave speeds, from the source to a receiver. Sound waves travel at a single speed in a given medium (for example, sound speed is 344 m/s in air at 20°C). It is beyond the scope of this manual to discuss in detail the complexities of vibration propagation and only a brief mention has been made to highlight the complex nature of this physical phenomenon.

# 3. EVALUATION OF VIBRATION IMPACT

Vibration impact is usually evaluated in terms of human response to building vibration. The first step is then to prescribe the vibration limits that are acceptable in a building from a human annoyance point of view. A number of guideline documents relating to human response to building vibration has been published (most of them in draft form) to date. The majority of the documents address human response to continuous vibration. Impulse vibration impacts produced by sources such as punch presses and infrequent events such as train pass-bys are not well understood. Several different approaches and suggested limits as well as only sketchy description of measurement procedure and instrumentation can be found in state-of-the-art documentation.

The vibration levels from a given source are established either through prediction or through measurements at the sensitive receptor location. Prediction of vibration level from a source is usually not very accurate and is dependent on various parameters, many of them not easily obtainable for land use planning purposes. In most instances the use of measurement procedures may be the only recourse in establishing the vibration levels.

If the sensitive location is within a building the levels can be directly compared to acceptable criteria and impacts can be evaluated. However, in land use compatibility assessment measurements are usually conducted on the ground where a particular sensitive building is to be constructed. The relationship between the outside level and the expected level inside the proposed building must be established. Unfortunately such a relationship is another complicated phenomenon, depending on soil conditions, building type and factors that control the coupling between the soil and the building. The building vibration level can vary from twice as large to smaller than the outside level. It is seen that vibration assessment is a complicated process depending on site specific conditions.

Three common sources of vibration impact and corresponding assessment procedures are outlined below. It must be pointed out that the list is not exhaustive, however, any vibration source can be analysed in similar fashion as to their impact. The first two are examples of sources that produce vibrations that are impulsive in nature and the third one is an example of a source that generates continuous vibration.

## 3.1 ASSESSMENT OF BLASTING VIBRATION

Blasting is used in quarrying and surface mining to fracture and separate various rock materials for easy handling and further processing. Excavation, preparation of foundations and trenching of sewage and water lines or other service or transmission lines running under the surface of the ground also, from time to time, requires the assistance of blasting. One of the unpleasant side effects of blasting is ground vibration.

Ministry publication NPC-119 sets the limits for ground borne vibrations due to blasting. Ministry publication NPC-207 (draft) establishes procedures and limits to assess impulsive vibration in residential buildings.

## 3.2 ASSESSMENT OF IMPULSE VIBRATIONS

Impulse vibration can be caused by the operation of a number of industrial sources such as punch presses, stamping presses, drop forges, etc.

NPC - 207 has been prepared by the Ministry to evaluate the impact of industrial sources.

## 3.3 ASSESSMENT OF RAILWAY VIBRATION

Available land for sensitive uses is becoming scarce in metropolitan areas. As a result, more and more sensitive developments are being built close to major train lines, and accurate impact assessment of new sensitive land uses beside railway lines is required.

The MOE criterion for an acceptable impact of ground-borne railway vibration is yet to be formally standardised. However, based on the currently available information including existing standards, scientific literature and past MOE's recommendations, the criterion should limit the vibration velocity to below about 0.1 mm/s, RMS, in the frequency range of about 10 to 100 Hz.

## 4. MEASUREMENT OF VIBRATION

The basic vibration measurement system includes a transducer, pre-amplifier and some means of analysing and displaying the transducer generated electrical output. Just as in sound measurements, the transducer is the most critical element in any vibration measurement system. The important characteristics of a transducer are the sensitivity, the frequency response and the linearity of the relationship between indicated and applied vibration amplitude at a given frequency. Other considerations are sensitivity to vibration in directions other than that intended to be measured and sensitivity to the environment (temperature, electrical fields, etc.). The associated electrical amplifiers, filters, integrators and recorders should have adequate frequency response, gain and linearity to ensure that they cause no distortion of the output signal.

## 5. VIBRATION INSTRUMENTATION

The most popular vibration transducer is the accelerometer; however, a vibration velocity transducer (pick-up) is also used in many applications.

### 5.1 ACCELEROMETERS

The accelerometer produces an electrical signal, the voltage of which is proportional to the acceleration experienced by the device. Shown in Figure 4.2 are several commercially available accelerometers along with a schematic showing basic construction and active elements. Basically, the accelerometer consists of a mass suspended on a spring between two piezoelectric crystals. These components are encased in a metal housing and attached to a base. When the assembly is mounted to a vibrating surface, the mass exerts an initial force on the crystals that is proportional to acceleration. From the piezoelectric effect of the crystals, a voltage proportional to the acceleration is produced and brought out through a connector to small easily attached cables. For accelerometers the output voltage sensitivity is usually rated in terms of millivolts per g, where g is the acceleration due to the earth's gravitational field.

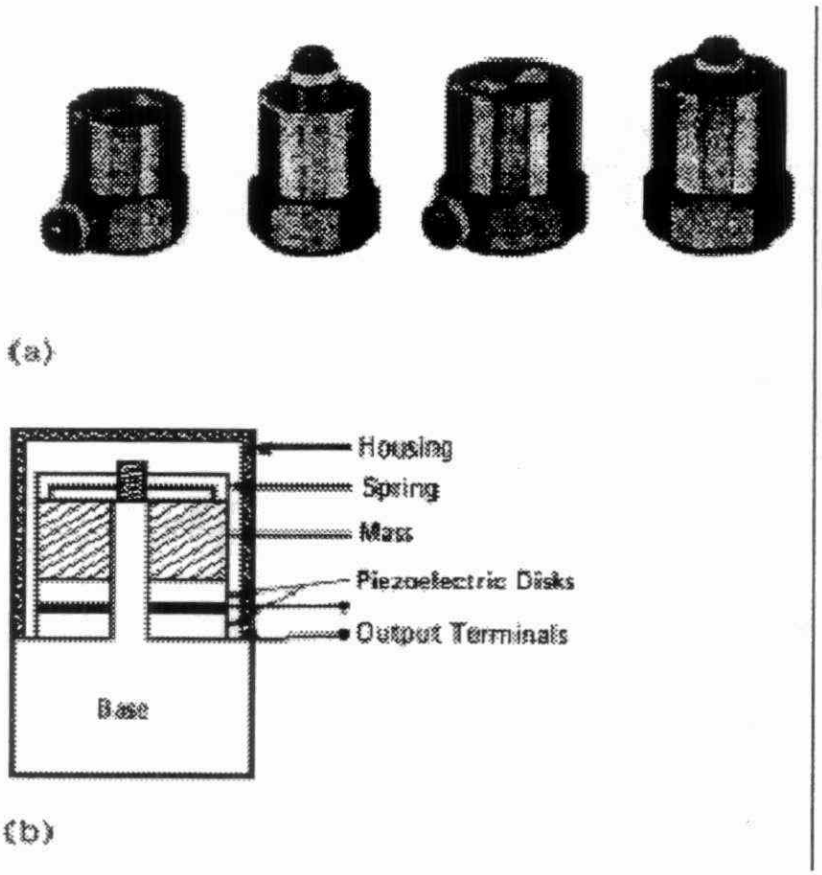


**Figure 4.2**
**a) Examples of Commercially Available Accelerometers**
**b) Basic Construction of an Accelerometer**

Typical sensitivities for commercially available piezoelectric accelerometers range from 10-60 mV/g over a wide frequency range. Accelerometers are small, lightweight, need no external voltage supply and have good high frequency response. However, they require a pre-amplifier to suitably condition their output (as do microphones).

## 5.2 VELOCITY PICK-UPS

Velocity transducers (pick-ups) provide an electrical signal whose voltage is proportional to the velocity of the vibrating surface to which it is mounted. The device consists primarily of a moving coil surrounded by a permanent magnet. As the coil moves due to the motion of the pick-up, a voltage is induced which is proportional to velocity. The induced signal is brought out through a connector to small easily attached cables.

The velocity pick-up has the advantage of not requiring pre-amplification. However, velocity pick-ups are large devices compared to accelerometers and extremely sensitive to magnetic fields common in industrial

environments. They have moving parts which are prone to wear and, due to high internal friction, are generally less sensitive than comparable size accelerometers. For all these reasons, the accelerometer is considered to be more versatile in vibration measurements.

If velocity or displacement is required rather than acceleration, it can be obtained knowing the vibration frequency, or very often the conversion to velocity and displacement from acceleration is done electronically using an integrator, so that an accelerometer can easily be used for velocity measurements.

## 5.3 VIBRATION TRANSDUCERS MOUNTING

Perhaps the most critical aspect of the use of vibration transducers is in the mounting. If the transducer is not solidly mounted to the vibrating surface, significant measurement errors may be expected.

In Figure 4.3 are shown several common methods.

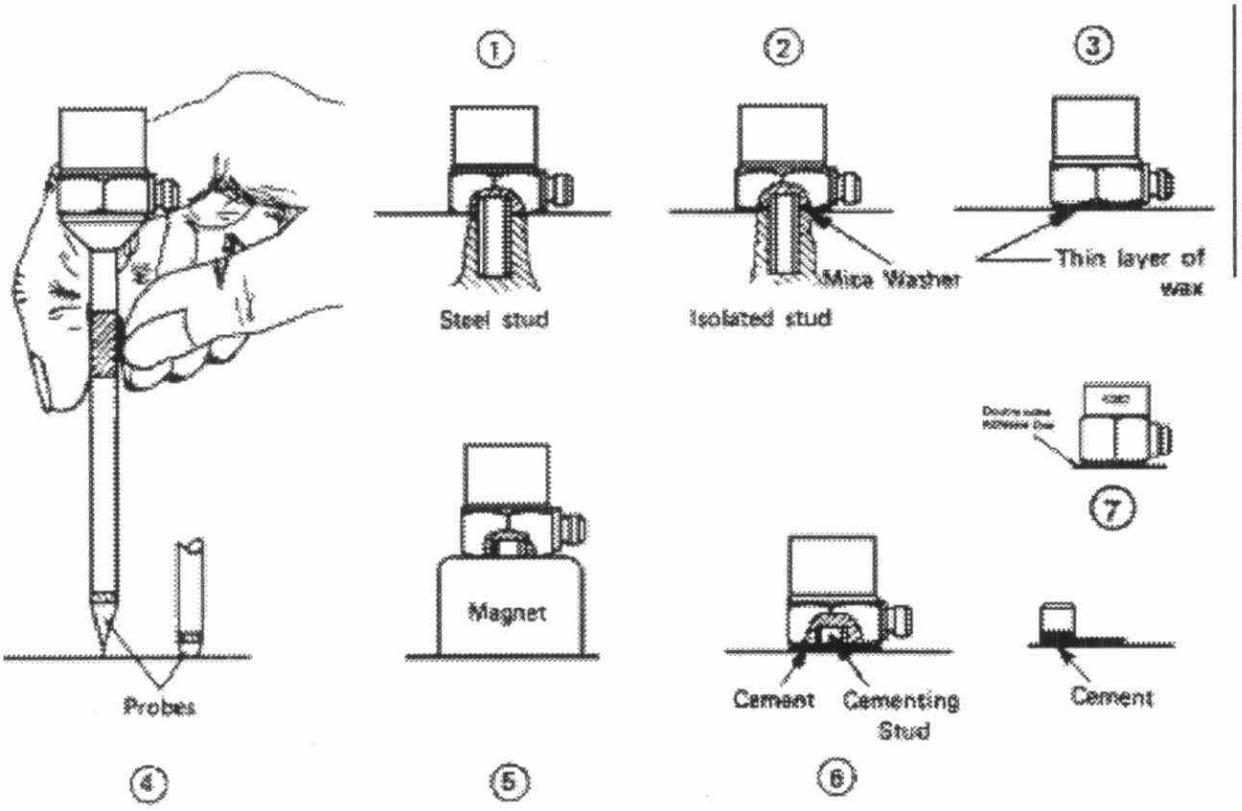


**Figure 4.3 Common methods for mounting accelerometers**

### Method 1 Mounting

This method is the best in terms of frequency response, approaching a condition corresponding to the actual calibration curve supplied with accelerometer. If the mounting surface is not quite smooth, it is a good idea

to apply a thin layer of silicon grease to the surface for threading down the accelerometer. This increases the mounting stiffness. It is essential whenever using a mounting screw not to tighten it fully, as one may introduce base bending affecting the sensitivity of the accelerometer.

**Method 2 Mounting**

This method is convenient when electrical isolation between the accelerometer and vibrating body is necessary. It employs the isolated stud and a thin mica washer. The frequency response is good due to the hardness of the mica.

**Method 3 Mounting**

This method employs a thin layer of wax for sticking the accelerometer under the vibrating surface. Surprisingly, this method yields a very good frequency response due to the stiffness of the wax. Caution is required, however, above room temperature, as the wax melts and the method fails.

**Method 4 Mounting**

This method employs a probe with interchangeable round and pointed tips. The method may be convenient for certain applications but should not be used for frequencies much higher than 1,000 Hz.

**Method 5 Mounting**

This method employs a permanent magnet which also gives electrical isolation from the vibrating specimen. A closed magnetic path is used and there is virtually no magnetic shield at the accelerometer position. This mounting should not be used for acceleration amplitudes higher than about 200 g or temperatures above 100°C.

**Method 6 Mounting**

This method is convenient when a cementing technique is appropriate. If the bond is good, the frequency response of the transducer is also good.

**Method 7 Mounting**

The most commonly used method in the Ministry is the double sided tape mounting. Double sided adhesive tape is a quick and easy medium for mounting accelerometers. Thin tape used on flat, smooth

surfaces gives fairly good results. Care must be taken to avoid the use of thick tapes as a significant reduction in the useful frequency range may result.

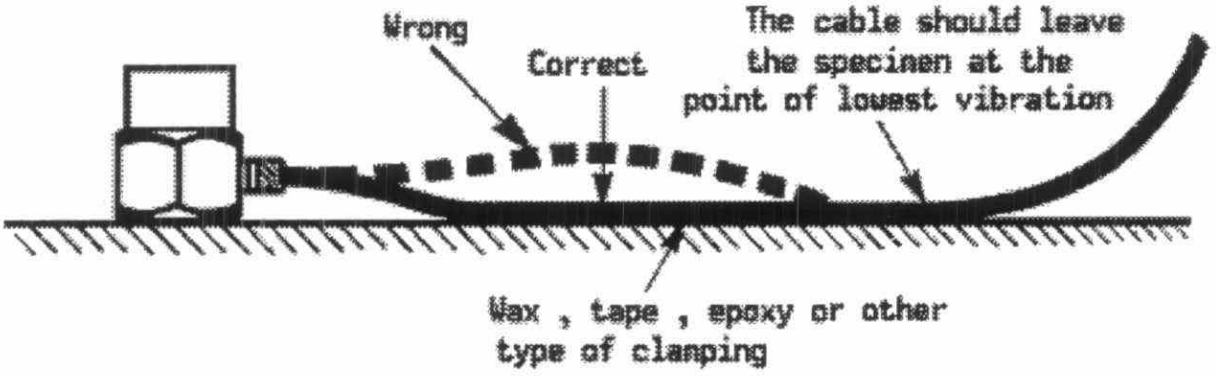


**Figure 4.4 Location of cable to avoid cable whip**

Some care must be given to avoid cable "whip". Here some method of clamping the electrical output cable to the surface must be found to avoid high level whipping motion of the cable relative to the accelerometer. If not attached securely, the cable will often experience fatigue failure at the terminal. Usually either wax, tape or glue, as illustrated in Figure 4.4 will be adequate.

## 5.4 PRE-AMPLIFIER

This component of the vibration measurement system increases the level of the transducer signal and provides an impedance matching device between the transducer and signal-processing equipment. Most transducer manufacturers supply an assortment of pre-amplifiers as optional equipment. For those measurement situations where long cable lengths are required, a charge type pre-amplifier is strongly recommended along with careful attention to the manufacturer's guidelines and directions.

## 5.5 VIBRATION PROCESSING AND ANALYSIS EQUIPMENT

The processing and analysis equipment for vibration equipment is essentially the same as that for sound measurement. It includes an amplifier, frequency filters, a detector, an overload indicator and an indicating meter.

The amplifier provides the dual function of matching the high electrical impedance of the filters and adjusting the signal level to meet relatively narrow dynamic range of the detector circuitry. It is protected

by an overload indicator that guarantees that the signal is not distorted from over driving the amplifier circuits. The detector determines which of the signal parameters RMS, Peak or Average is displayed on the meter. Usually it will be the power content of the signal that is of interest and, therefore, the RMS value of the signal is needed from the detector.

A sound level meter can also be used as a vibration meter. However, care should be exercised due to the frequency, and other, limitations of sound level meter based systems.

## 5.6 VIBRATION CALIBRATORS

Every vibration transducer is individually calibrated accompanied by the calibration chart. However, in normal use, vibration transducers are often handled roughly which may result in a significant change in characteristics. It is, therefore, recommended to make a periodic check of the sensitivity calibration to determine if the transducer is not damaged.

The most reliable method of calibration check is to use a calibrated vibration source designed to vibrate the transducer at a known amplitude and frequency. Such a calibrator has a small built-in shaker table and a generator which can be adjusted to vibrate at predetermined amplitude under accurately controlled frequency. The sensitivity calibration of a transducer is checked by fastening it to the shaker table and noting the output when vibrated at calibration frequency and amplitude. Calibration accuracy is usually within +2% when used carefully.

Another application for the portable calibrator is the checking of a complete measuring or analysing set up before the measurements are made.

## APPENDIX 5. NOISE BARRIERS

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Describe the concepts of barrier attenuation
2. Understand Path Length Difference and Fresnel Number
3. Describe the differences between attenuation by thick and thin barriers

## NOISE BARRIERS

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# NOISE BARRIERS

## 1. INTRODUCTION

Noise barriers provide attenuation by shielding the receiver from the source of sound.

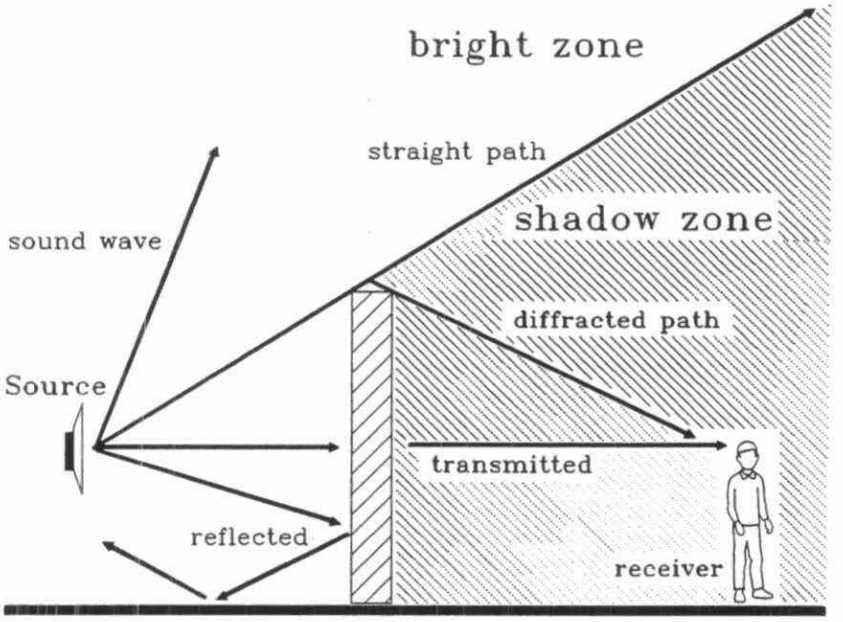


**Figure 5.1 Effect of a Barrier on Sound Waves**

Figure 5.1 shows a progression of sound waves crossing a barrier (a wall, fence or similar construction). The sound waves near the top of the figure pass clearly over the barrier and are not affected by it. Sound waves which pass close to the barrier are diffracted by the barrier and hence bent around as shown in the figure. A receiver standing in the region of the bent sound waves (shadow zone) will hear sound at a reduced level than a receiver standing in the area of the unaffected sound waves (bright zone). This process of sound wave diffraction is similar to the process of diffraction in the study of the behaviour of light.

## 2. PATH LENGTH DIFFERENCE AND FRESNEL NUMBER

From optical diffraction theory, the sound attenuation of an acoustical barrier is found by calculating the "path length difference" or the extra distance the sound is forced to travel because of the presence of the barrier.

## 2.1 THIN BARRIERS

Figure 5.2 shows a barrier placed between a source and a receiver. In the absence of the barrier, the sound travels directly between the source and the receiver, along the path shown as the distance d. However, with the barrier in place, the sound must travel from the source to the top of the barrier (distance a) and from the top of the barrier to the receiver (distance b), i.e. with the barrier in place the sound must travel through a total distance of a + b. Subtracting d from a + b gives the extra distance the sound must travel because of the barrier.

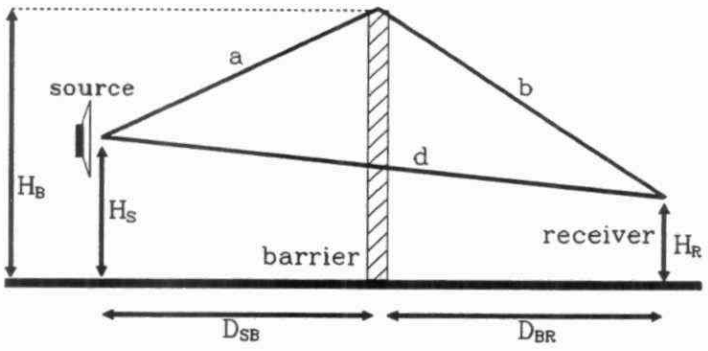


**Figure 5.2 Definition of Path Length Difference (PLD)**

Figure 5.2 defines the appropriate parameters: the source barrier distance $D_{SB}$, the barrier receiver distance $D_{BR}$, the source height $H_S$, the barrier height $H_B$ and the receiver height $H_R$.

The path length difference (PLD), $\delta$, can then be calculated from:

$$\delta = a + b - d$$

$$\text{where} \quad a = \sqrt{(a_1 + a_2)}, \quad a_1 = (H_B - H_S)^2, \quad a_2 = D_{SB}^2$$
$$b = \sqrt{(b_1 + b_2)}, \quad b_1 = (H_B - H_R)^2, \quad b_2 = D_{BR}^2$$
$$\text{and} \quad d = \sqrt{(d_1 + d_2)}, \quad d_1 = (H_S - H_R)^2, \quad d_2 = (D_{SB} + D_{BR})^2$$

## 2.2 THICK BARRIERS

It is often possible to use a row of townhouses or even an apartment block as a noise barrier. In this case some extra sound reduction is achieved as the sound is diffracted around the two upper edges of the building (see Figure 5.3). Again the PLD can be used as a simple indicator of the sound reduction. If the building thickness is defined as T, then the calculation of PLD, $\delta$, is as follows:

$$\delta = a + b + T - d$$

*where* $a = \sqrt{(a_1 + a_2)}$, $a_1 = (H_B - H_S)^2$, $a_2 = D_{SB}^2$

$b = \sqrt{(b_1 + b_2)}$, $b_1 = (H_B - H_R)^2$, $b_2 = (D_{BR} - T)^2$

*and* $d = \sqrt{(d_1 + d_2)}$, $d_1 = (H_S - H_R)^2$, $d_2 = (D_{SB} + D_{BR})^2$

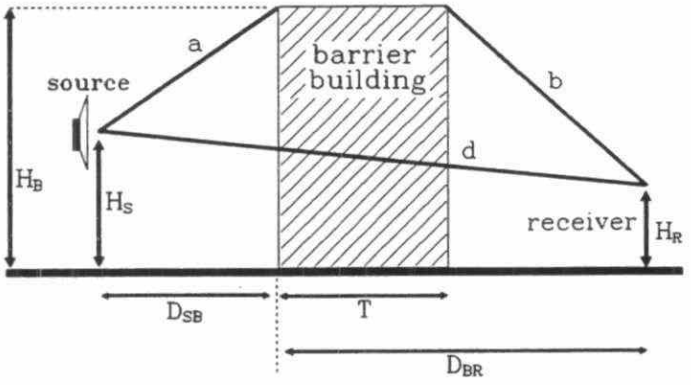


**Figure 5.3 Calculation of PLD for a Thick Barrier**

Care should be taken when calculating PLD that the receiver is in the shadow zone, that is, the source cannot be seen by the receiver. In this situation the PLD is given a positive sign and a significant sound attenuation will result. If, however, the source can be seen by the receiver despite the presence of the barrier, then the receiver is in the bright zone and the PLD should be given a negative sign. In the later case the barrier will give very little, or no, sound reduction at the receiver position.

## 2.3 FRESNEL NUMBER

Once the PLD has been calculated, the sound attenuation of the barrier can only be calculated with a knowledge of the wavelength or frequency of the sound wave under consideration. This is necessary as low frequency sound (or long wavelength) can be diffracted or "bent" more easily than high frequency sound (or short wavelength). Following the optical diffraction theory, the "Fresnel Number" (N) must be determined as follows:

*Fresnel Number*, $N = \frac{2\delta}{\lambda}$ , where $\lambda$ is the wavelength and $\delta$ is the PLD.

As we usually work with frequency rather than wavelength, it is useful to convert the formula for N into a form involving frequency $f = c/\lambda$, where c is the speed of sound in air.

Thus $$N = \frac{2 f \delta}{c}$$

Care should be taken when using this equation to use a consistent set of dimensions. If the PLD is calculated in metres, then the speed of sound used must be in metres/ second. If the PLD is calculated in feet, then the speed of sound must be in feet/second.

$$\textit{Fresnel Number,}\quad N = \frac{2 f \delta}{343} \quad (\textit{PLD } \delta \textit{ in metres})$$

$$\textit{Fresnel Number,}\quad N = \frac{2 f \delta}{1125} \quad (\textit{PLD } \delta \textit{ in feet})$$

### 2.3.1 Road and Rail Noise

It is clear that in order to calculate N, either the frequency of the sound must be known, or if the sound covers a wide frequency range, some frequency representative of the source noise emissions must be assumed. The Ministry of Environment and Energy uses a frequency of 500 Hz to represent both the road transportation and the train transportation noise.

Calculation of the conversion factors from $\delta$ to N is simplified once the representative frequency is established. The Fresnel number for a frequency of 500 Hz is:

$$N = 2.915\ \delta \quad (\textit{PLD } \delta \textit{ in metres})$$
$$= 0.889\ \delta \quad (\textit{PLD } \delta \textit{ in feet})$$

## 3. ATTENUATION FOR POINT AND LINE SOURCES

A noise barrier provides different values of sound attenuation for stationary point sources and line sources. An array of moving point sources should be considered as line sources. In general, the attenuation for a line source is less than that for a point source.

The barrier attenuation for a point source, $\Delta_p$, assuming an infinite barrier, is given by:

$$\Delta_p = 5 + 20 \log \left[ \frac{\sqrt{2\pi N}}{\tanh \sqrt{2\pi N}} \right], \quad \textit{for } -0.19 < N \leq 12.65$$
$$= 24\ dB \quad , \quad \textit{for } N > 12.65$$

where $N = N_o \cos \phi$

$N_o = 2\,\delta / \lambda$, is the Fresnel Number

and $\phi$ is the angle subtended by the line connecting the source and receiver and a line perpendicular to the barrier.

The above implies that the point source attenuation is limited to a maximum of 24 dB.

For a line source, the attenuation provided by an infinite barrier is obtained by integrating the above expression from $-\pi/2$ to $\pi/2$, and is given by:

$$\Delta_l = 20 \log \left[ \frac{1}{\pi} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} 10^{-\frac{\Delta}{10}} \, d\phi \right]$$

$$\textit{where} \quad \Delta = 5 + 20 \log \left[ \frac{\sqrt{2\pi N}}{\tanh \sqrt{2\pi N}} \right], \quad \textit{for } -0.19 < N \leq 5.03$$

$$= 20 \ dB \qquad , \quad \textit{for } N > 5.03$$

Figure 5.4 gives the attenuation provided by an infinite barrier for both a point and a line source. For a point source, the assumption is of normal incidence, i.e. $\phi = 0$.

The upper curve on Figure 5.4 applies to a point source such as a stationary machine, car or truck, or an idling locomotive. The lower curve applies to a line source such as a continuous flow of traffic along a roadway or the wheel-rail noise from a long freight train. It can be seen from the graph that the attenuation provided by a barrier is less for line sources than point sources.

The graphs in Figure 5.4 assume:

- That the barrier is very long (at least eight times the source to receiver distance) or is turned through a right angle away from the source at both ends to protect the receiver from the sides.

- That the barrier does not allow sound to penetrate through itself and thus raise sound levels in the shadow zone. To avoid this effect, the barrier can be made of any material (solid wood, masonry or earth in the form of a berm) so long as it has a surface mass density of 20 kg/m$^2$ (4 lbs/ft$^2$) and has no holes or gaps.

- That the barrier is at right angles to a line drawn from the receiver to the source (for a point source) or a line drawn from the receiver perpendicular to the source (for a line source).

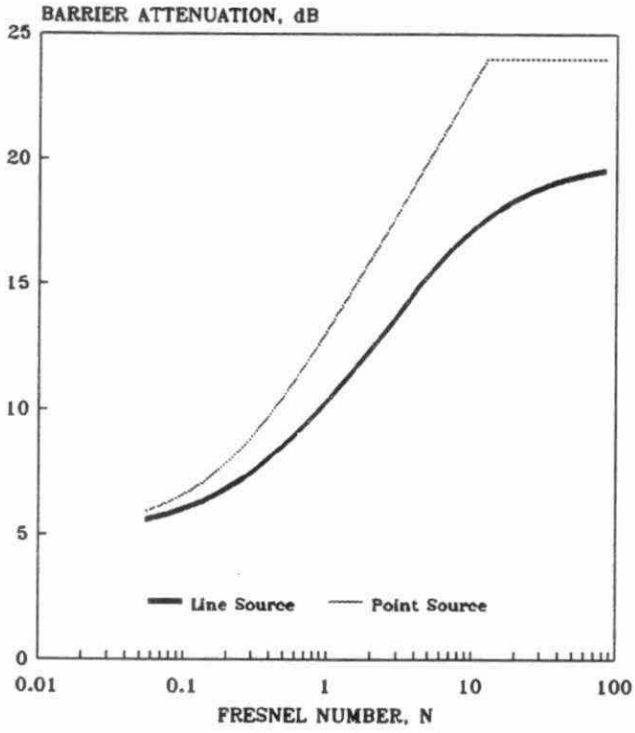


**Figure 5.4 Infinite Barrier Attenuation**

In many practical cases, conditions described above are not met and the barrier cannot be considered infinite. Therefore, the attenuation provided by a finite barrier must be calculated. Finite barrier attenuation is obtained from the above equations, replacing the angles $-\pi/2$ and $\pi/2$, (i.e. -90° and 90°) by the appropriate values.

It was indicated earlier that in some instances, a barrier is extended or wrapped around a corner lot or a row of houses to simulate an infinite barrier. A simple example is shown in Figure 5.5. The barrier attenuation calculation depends on the angle subtended at the receiver by the barrier. For the receptor location shown in Figure 5.5, the wrap around section of the barrier can be represented by an equivalent barrier section which considerably extends the overall length of the barrier parallel to the roadway.

## 4. MINIMUM HEIGHT REQUIREMENT FOR BARRIERS

The equations presented in the previous sections predict a smooth decrease of barrier attenuation to '0 dB' by including negative PLD values, i.e. by including receiver positions in the bright zone. In certain situations, however, even small topographical variations may in theory predict barrier attenuations of 3 to 4 dB where the receiver would be well in the bright zone.

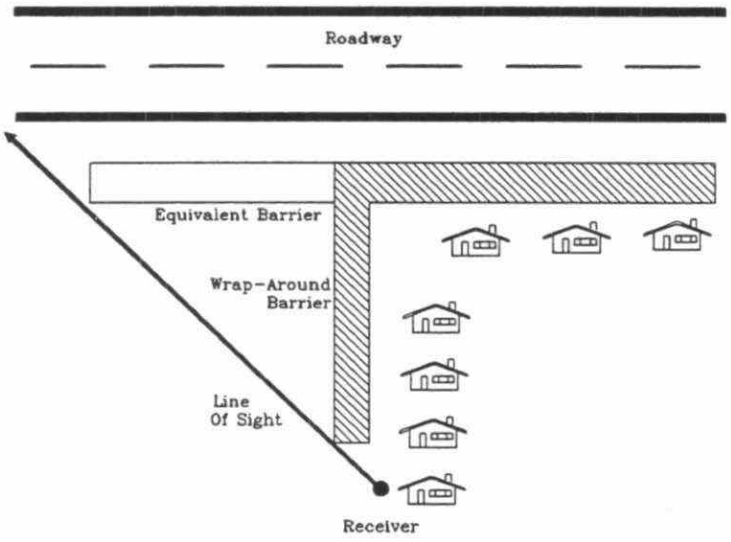


**Figure 5.5 Example of a Wrap-around Barrier**

To avoid these unrealistic results, where barrier attenuation predictions can be erroneously applied, the Ministry's guidelines require that if a barrier is used as a physical noise control measure, its height must be such that the barrier breaks the line of sight between the source and receiver.

## APPENDIX 6. INDUSTRIAL NOISE AND THE APPROVAL PROCESS

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Identify the types of stationary noise sources for the purposes of complaint investigation and approvals process.

2. State the applicable noise criteria for complaint investigation and approval.

3. Provide details of information required for the assessment of stationary sources of sound.

4. Describe the predictable worst case impact.

5. Know standard conditions for Certificates of Approval.

## INDUSTRIAL NOISE AND THE APPROVAL PROCESS

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# INDUSTRIAL NOISE AND THE APPROVAL PROCESS

## 1. SCOPE

This Chapter addresses noise produced by all stationary sources of sound including noise produced by industrial sources. These sources are defined below. The noise impact produced by the stationary sources is considered in the context of:

- assessment of noise complaints by residents of existing sensitive land uses that are a result of the operation of existing stationary sources of sound;
- planning of new sensitive land uses such as residential subdivisions adjacent to existing stationary sources of sound;
- approval of new stationary sources of sound such as new or expansion of existing industrial facilities.

## 2. BACKGROUND

Although transportation noise is the main contributor to community noise, those exposed often develop a partial empathy toward transportation noise because they anticipate a personal use for the particular mode of transportation. In case of industrial noise, with the exception of persons whose livelihood depends upon the particular industry, similar empathy is generally lacking. The possible tax benefits from nearby industry do not carry much weight in a community that believes property values have decreased because of increased noise.

Furthermore, industrial noise creates adverse community reaction because of some or all of the following characteristics:

- presence of discrete tones, beats or rumble
- presence of impulsive or impact events
- rapid variation with time
- interference with sleep and speech
- conveying a fear message
- reminder of other side effects
- location of the industry in otherwise quiet environment

Community response to industrial noise depends on both the absolute sound level of intruding noise and the increase in sound level relative to the previous ambient sound level in the community.

The variety of industrial processes is such that attempting to set emission standards for each piece of industrial equipment is generally impractical. Acceptability of industrial noise depends strongly on factors other than the noise level of the equipment. For example, the industry may be surrounded only by other industries and consequently may not be a nuisance.

A more realistic approach to the environmental noise control of industries is to set acceptable noise criteria for noise sensitive land uses and to plan future development to avoid incompatible neighbours being located adjacent to one another.

**In Ontario, the essence of noise guidelines specified by the Ministry of the Environment is that stationary sources of sound such as industrial operations should not generate more noise at an adjacent residential receptor location than the pre-existing vehicular traffic noise in the area in which it is located.**

## 3. STATIONARY SOURCES

The objective of the definition of a stationary source of sound is to address sources such as industrial and commercial establishments or ancillary transportation facilities. In order to further clarify the scope of the definition, the following list identifies examples of installations, equipment, activities or facilities that are included and those that are excluded as stationary sources.

### 3.1 INCLUDED SOURCES

Individual stationary sources such as:

- Heating, ventilating and air conditioning (HVAC) equipment;
- Rotating machinery;
- Impacting mechanical sources;
- Generators;
- Burners;
- Grain dryers.

Facilities, usually comprising many sources of sound. In this case, the stationary source is understood to encompass all the activities taking place within the property boundary of the facility. The following are examples of such facilities:

- Industrial facilities;
- Commercial facilities;
- Ancillary transportation facilities;
- Aggregate extraction facilities;

Warehousing facilities;

Maintenance and repair facilities;

Snow disposal sites;

Routine loading and unloading facilities (supermarkets, assembly plants, etc.).

Other sources such as:

Car washes;

Race tracks;

Firearm Ranges;

## 3.2 EXCLUDED SOURCES

Specific sources or facilities:

Construction activities;

Transportation corridors, i.e. roadways and railways;

Residential air conditioning devices including air conditioners and heat pumps;

Gas stations;

Auditory warning devices required or authorized by law or in accordance with good safety practices;

Occasional movement of vehicles on the property such as infrequent delivery of goods to convenience stores, fast food restaurants, etc.

Other noise sources, normally addressed in a qualitative manner in municipal noise by-laws:

The operation of auditory signalling devices, including but not limited to the ringing of bells or gongs and the blowing of horns or sirens or whistles, or the production, reproduction or amplification of any similar sounds by electronic means;

Noise produced by animals kept as domestic pets such as dogs barking;

Tools and devices used by occupants for domestic purposes such as domestic power tools, radios and televisions, etc., or activities associated with domestic situations such as domestic quarrels, noisy parties, etc;

Noise resulting from gathering of people at facilities such as restaurants and parks.

Activities related to essential service and maintenance of public facilities such as but not limited to roadways, parks and sewers, including snow removal, road cleaning, road repair and maintenance, lawn mowing and maintenance, sewage removal, garbage collection, etc.

### 3.3 POINT OF RECEPTION

The assessment of noise impact is generally performed at a point of reception. The point of reception is defined as any point on the premises of a person where sound or vibration originating from other than those premises is received. Furthermore, the point of reception must be in a residential area or a quiet zone. In rural areas, the point of reception must be within 30 m of a dwelling or a camping area.

## 4. NOISE CRITERIA

For approval of new noise sources and for complaint investigations, two MOE guidelines contain the applicable sound level limits for stationary sources, depending on the location of the point of reception. Publication NPC-205, Sound Level Limits for Stationary Sources in Class 1 & 2 Areas (Urban), deals with noise impact on points of reception located in typically urban or suburban areas. Publication NPC-232, Sound Level Limits for Stationary Sources in Class 3 Areas (Rural), deals with points of reception in typically rural areas. The limits presented in both publications are designed for the control of noise from sources located in industrial, commercial or residential areas. The prescribed limits apply at a point of reception.

Sound level limits do not apply to non-stationary noise sources and neither do they apply to any equipment, apparatus or device used in agriculture for food crop seeding, chemical spraying or harvesting. In addition, several specific noise sources have been addressed in separate Technical Publications. Limits for residential air conditioners are contained in Publication NPC-216 - Residential Air Conditioning Devices, and the limits for blasting operations in quarries and surface mines are contained in Publication NPC-119 - Blasting.

For planning of sensitive land uses, the MOE guidelines are contained in Publication LU-131, Noise Assessment Criteria in Land Use Planning.

### 4.1 STEADY SOUND

The basic provision of NPC-205 is specified in Section 8.(2) and applies to all types of sound, excluding impulsive sounds. An assessment of noise impact due to source operation is made in terms of the one hour equivalent sound level descriptor $L_{eq}$. The limit on the equivalent sound level produced by the source is given by the minimum one hour equivalent sound level ($L_{eq}$) caused by road traffic.

## 4.2 IMPULSIVE SOUND

For impulsive sound, the general sound level limit is given in Section 8.(1) of NPC - 205. The impact of noise from impulsive sources is expressed in terms of the Logarithmic Mean Impulse Sound Level, $L_{LM}$, defined in a following formula:

$$L_{LM} = 10 \log \left[ \frac{1}{N} \left( 10^{\frac{dBAI_1}{10}} + 10^{\frac{dBAI_2}{10}} + \ldots . 10^{\frac{dBAI_N}{10}} \right) \right]$$

where $dBAI_1$ , $dBAI_2$ ... $dBAI_N$ are the N impulse sound levels measured in dBAI.

The Hourly Equivalent Sound Level, $L_{eq}$, caused by road traffic at the point of reception is the applicable general sound level limit in both cases of impulsive and non-impulsive sources.

It has to be recognized that some industrial impulsive noises are of highly intrusive nature, and are annoying no matter in what kind of environment they are generated. Two specific sound level limits have been established for these types of noise, depending on the frequency of their occurrence.

The first limit set for specific industrial sources generating frequent impulsive sounds such as metal working operations (including but not limited to forging, hammering, punching, stamping, cutting, forming and moulding) is specified in Section 9.(1) and is expressed in terms of the Logarithmic Mean Impulse Level descriptor, $L_{LM}$. The applicable limit for these sources is 60 dBAI if they were in operation before January 1, 1980, and otherwise it is 50 dBAI. A detailed procedure for the measurement of frequent impulsive sounds is described in Sections 3.4(f) of the Technical Publication NPC-103, Procedures. As a basic requirement for the calculation of $L_{LM}$ , a minimum number of 20 impulsive events shall be measured within a continuous period of 20 minutes.

The other specific impulsive limit, set for operations generating infrequent impulsive sounds which occur as single, seemingly independent, event, is specified in Section 9.(3). The applicable limit is 100 dBAI, and the procedure for such single impulsive event measurement is described in Section 3.4(g) of the Technical Publication NPC-103, Procedures.

## 4.3 MORE THAN ONE APPLICABLE LIMIT

A pre-emption is included in Section 12 of NPC-205, allowing for the selection of least restrictive limits if more than one sound level limit is applicable for a particular operation.

Where limits expressed in terms of energy equivalent sound levels ($L_{eq}$) are applicable to an industrial operation, an exclusion is specified in Section 13 that removes any restriction on industrial operation generating an hourly $L_{eq}$ level of 45 dBA or less at the point of reception.

## 5. COMPLAINT INVESTIGATION

Investigations of noise complaints regarding industrial noise sources and other stationary sources of sound should utilize the noise criteria in Publications NPC-205 or NPC-232. The selection of the applicable publication is governed by the location of the point of reception, depending on whether it is located in Class 1, 2 or 3 area. Although the publications contain guidelines on the appropriate classification of areas, the selection of the applicable publication, NPC-205 or NPC-232, is ultimately made at the discretion of the investigator.

## 6. PLANNING OF SENSITIVE LAND USES

The impact assessment of noise produced by stationary sources is performed using criteria and methods prescribed in MOE Publication LU-131. In most instances, the criteria of LU-131 are identical to the criteria in Publications NPC-205; however, some differences exist. For example, LU-131 requires that the night-time noise impact be assessed only in the plane of a bedroom window whereas, according to NPC-205, the impact has to be assessed at any point of reception.

It is also of note that Publication LU-131 does not deal with the noise impact of stationary sources on receptors in Class 3 (rural) areas. Whereas NPC-232 addresses the noise impact of stationary sources on existing rural receptors such as single dwellings, the objective of LU-131 is to address large developments such as subdivisions which due to their size and complexity could not be considered as rural.

## 7. APPROVAL OF NEW NOISE SOURCES

For the approval of stationary sources of sound, the MOE uses basically the same criteria as those applied to the impact assessment of existing sources, facilities or operations. The criteria described in Publication NPC-205 that are used for a complaint investigation of an industrial facility, for example, would be utilized by the Ministry's staff to assess the impact (and the compliance) of a new stationary noise source such as an industrial installation or facility. Publication NPC-232, is used by the Ministry for the impact assessment where the point of reception is located in a rural area.

Under the provision of Section 9 of the Environmental Protection Act (EPA), the MOE administers certification of new equipment or installations that may discharge a contaminant into the natural environment. Sound and vibration are defined as contaminants under the Act and equipment that is

producing or is likely to produce sound or vibration that may cause an adverse effect require a Certificate of Approval (Air) from the MOE. The sources that require a Certificate of Approval are identified in an MOE document entitled Guide to Applying for Approval (Air): Noise and Vibration (attached).

The regulations under the Aggregate Resources Act require that new aggregate extraction facilities comply with Provincial Guidelines. With regard the noise and vibration, the applicable provincial guidelines are the MOE guidelines NPC-119, Blasting, NPC-205, Sound Level Limits for Stationary Sources in Class 1 and 2 Areas (Urban) and NPC-232, Sound Level Limits for Stationary Sources in Class 3 Areas (Rural). Other agencies such as Municipalities or the Ministry of Municipal Affairs and Housing request comments on various proposals from the MOE and the MOE would utilize the criteria in NPC-205 or NPC-232 to provide advice and formulate comments.

## 7.1 INFORMATION REQUIREMENTS - APPLICANTS

In order to assist proponents of new installation/equipment applying for Certificates of Approval (Air) in determining what information may be required, the MOE has produced a document entitled Guide to Applying for Approval (Air): Noise and Vibration (attached). This document is also available on request from the Approvals Branch of the MOE.

Publication NPC-233, Information to be Submitted for Approval of Stationary Sources of Sound, presents the required technical information that proponents may be required to submit in order to allow MOE's "noise" staff to assess the proposals.

## 7.2 PREDICTABLE WORST CASE IMPACT

The assessment of noise impact requires the determination of the "predictable worst case" impact. The "predictable worst case" impact assessment should establish the largest noise excess produced by the source over the applicable limit. The assessment should reflect a planned and predictable mode of operation of the stationary source.

It is important to emphasize that the "predictable worst case" impact does not necessarily mean that the sound level of the source is highest; it means that the excess over the limit is largest. For example, the excess over the applicable limit at night may be larger even if the day-time sound level produced by the source is higher.

## 8. REFERENCES


1. Guide to Applying for Approval (Air): Noise and Vibration
2. NPC-205, Sound Level Limits for Stationary Sources in Class 1 & 2 Areas (Urban)
3. NPC-206, Sound Levels due to Road Traffic
4. NPC-232, Sound Level Limits for Stationary Sources in Class 3 Areas (Rural)
5. NPC-233, Information to be Submitted for Approval of Stationary Sources of Sound
6. NPC-207, Impulse Vibration in Residential Buildings (draft)
7. NPC-119, Blasting
8. NPC-216, Residential Air Conditioning Devices
9. LU-131, Noise Assessment Criteria in Land Use Planning

Ontario

*MINISTRY OF THE ENVIRONMENT*

# Guide to Applying for Approval (Air): Noise and Vibration

**November 1995**
**(Revised April 1998)**

*Noise and vibration impacts of proposed equipment/facilities are considered in the course of assessing applications for Certificates of Approval (Air), in accordance with Section 9 of the Environmental Protection Act. The purpose of this Guide is to assist proponents in determining what information should be submitted when applying for Certificates of Approval (Air) for equipment/facilities that may produce noise or vibration impact. All applications for Certificates of Approval (Air) for equipment/facilities that produce noise and/or vibration must include the relevant Information Request Forms with the Mandatory Information. This Guide supplements the general information contained in*

*Guide for Applying for Approval (Air), Approvals Branch, Ministry of the Environment, November 1994*

*The following noise and vibration guidelines published by this Ministry contain additional technical information:*

*NPC-205 Sound Level Limits for Stationary Sources in Class 1 & 2 Areas (Urban), October 1995*
*NPC-206 Sound Levels due to Road Traffic, October 1995*
*NPC-232 Sound Level Limits for Stationary Sources in Class 3 Areas (Rural), October 1995*
*NPC-233 Information to be Submitted for Approval of Stationary Sources of Sound, October 1995*
*NPC-207 Impulse Vibration in Residential Buildings (draft), November 1983*

## PROCEDURE

Within the review of the application for Certificate of Approval (Air), the noise and vibration component is assessed separately from the air component. In order to expedite the approval process, applicants should follow the steps set out below:

- According to Section 1, identify the category of the equipment/facility;
- Complete the Information Request Form - Detailed, attached to this document, if the proposed equipment/facility falls within one of the two categories identified in Sections 1.(1) and 1.(2);
- Complete the Information Request Form - Simple, attached to this document, if the proposed equipment/facility does not fall within the two categories identified in Sections 1.(1) and 1.(2);
- The Information Request Form - Simple is the minimum requirement for all applications for Certificates of Approval (Air);
- For specifically identified equipment/facilities, e.g. diesel/gas generator sets and fans, complete and submit the separate Information Request Form, attached to this document;
- In cases of complex or multiple sources, submit the information in the form of a report, prepared by a qualified acoustical or vibration consultant. Consult Publication NPC-233 for details on the technical requirements.

In general, the assessment of noise and vibration impacts is performed at critical points of reception[1]. Although the mandatory information is usually sufficient for the impact assessment, additional information may in some cases be required. As stated above, an acoustical report is required in cases of complex or multiple sources.

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1 "Point of reception" means any point on the premises of a person where sound or vibration originating from other than those premises is received.

For the purpose of verifying compliance with Section 9 of the Act, the point of reception may be located on any of the following existing or zoned for future use premises: permanent or seasonal residences, hotels/motels, nursing/retirement homes, rental residences, hospitals, camp grounds, and noise sensitive buildings such as schools and places of worship.

For equipment/facilities proposed on premises such as nursing/retirement homes, rental residences, hospitals, and schools, the point of reception may be located on the same premises.

## 10. CATEGORIZATION OF NOISE SOURCES

Equipment/facilities that produce noise and vibration are categorized by their potential to create adverse effects. Two groups of noise/vibration sources are identified: the first group includes equipment/facilities which may have a potential adverse effect on points of reception located within a 500 metre radius; the second group includes the most significant noise sources (equipment/facilities) which may have a potential adverse effect on points of reception located within a 1000 metre radius.

### (1) Equipment/facilities with 500 metre Influence Radius

If the proposed equipment/facility is identified as, or closely resembles, one of the sources within the following list and any point of reception is within 500 metres of the proposed equipment/facility, the applicants must complete and submit the Information Request Form - Detailed, along with the application for a Certificate of Approval (Air):

Aggregate Handling Facilities
Air Conditioning Units (Industrial/Commercial)
Air Make-up Units
Baghouses
Blow Moulding
Boilers
Burners
Car Washes
Chillers
Compressors
Concrete Manufacturing/Processing
Condensers
Cooling Towers
Cyclones
Dust Collectors
Electric Motors
Engines - Diesel/Natural Gas, Continuous & Standby (see forms in Section 2)
Fans and Blowers (see forms in Section 2) (see also Fans and Blowers in Section 1.(2))
Foundries
Furnaces
Garbage Compactors
Grain Dryers
Incinerators
Landfill/Composting/Waste Reduction Facilities
Material Handling Facilities
Metal Working
Paint Spray Booths
Pneumatic Equipment (used outdoors)
Pumps
Ready-Mix Plants
Refrigeration Equipment
Sandblasting
Scrubbers
Sewage Treatment Plants
Shredders
Soil/Groundwater Rehabilitation Systems
Stamping and Forging Presses
Transformers
Tub Grinders/Wood Chippers/Debarking Drums
Turbines (Steam)
Valves/Vents/Jets/Nozzles
Water Treatment Plants
Welding
Woodworking

### (2) Equipment/facilities with 1000 metre Influence Radius

If the proposed equipment/facility is identified as, or closely resembles, one of the sources within the following list and any point of reception is within 1000 metres of the proposed equipment/facility, the applicants must complete and submit the Information Request Form - Detailed, along with the application for a Certificate of Approval (Air):

Arc Furnaces
Asphalt Plants
Blowdown Devices
Cogeneration Facility
Crushing Operations
Flares
Fans and Blowers - all pressure blowers and large induced draft fans with flow rates in excess of 100,000 cfm or static pressures in excess of 5 inches water gauge (see forms in Section 2).
Firearm Ranges
Gas Turbines
Motor Vehicle Race Tracks

## 11. INFORMATION REQUEST FORMS

Separate Information Request Forms have been prepared for equipment/facilities most frequently subject to noise and vibration impact assessment and are attached to this document.

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## APPENDIX 7. BLASTING

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Understand the principles of blasting noise and vibration generation.
2. Understand the prediction methods for blasting noise and vibration.
3. Describe the limits for blasting noise and vibration.

## BLASTING

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# BLASTING

The objective of blasting is to fracture material so that it can be easily removed. The blast explosion creates a high pressure pulse that results in airborne sound (overpressure) and ground-borne vibration which propagate away from the blast location and may affect nearby structures and occupants.

Blast induced noise as well as vibration can have a significant environmental impact. Excessive blasting has a potential of causing structural damage to buildings. Even safe blasting practices can result in annoyance to residents around the blast site.

## 1. GROUND VIBRATION PRODUCED BY BLASTING

### 1.1 GENERATION AND PROPAGATION

Some of the energy of the blast which is not dissipated in the process of shattering the material surrounding the explosion is propagated as elastic (vibration) disturbance in the ground. Some energy is also released into the air and propagates as sound. The vibration disturbance separates into three or four types of ground waves which travel at different speeds.

At short range, the vibration wave radiates spherically and its amplitude diminishes inversely with the distance from the blast. At larger distances from the blast, the vibration wave splits into three types of waves which travel at different speeds. The dominant wave is the "slow" surface wave. The magnitude of the surface wave decreases less with distance than the other types of ground waves: the compression P-wave and the shear S-wave.

For quarry blasting, vibration levels at receptors located behind the quarry face are generally higher than those in front of the face.

Particle movement in the wave is transferred in three mutually perpendicular directions:

- Longitudinal (radial), back and forth particle movement in the same direction that the vibration wave is travelling.
- Vertical, up and down particle movement perpendicular to the direction the vibration wave is travelling.

- Transverse, left and right particle movement perpendicular to the direction the vibration wave is travelling.

All three components, i.e. longitudinal, vertical and transverse, are necessary to completely describe the vibration intensity, since the particles will be oscillating in a three-dimensional space.

An example of quarry blast time histories and frequency spectra is shown in Figure 7.1.

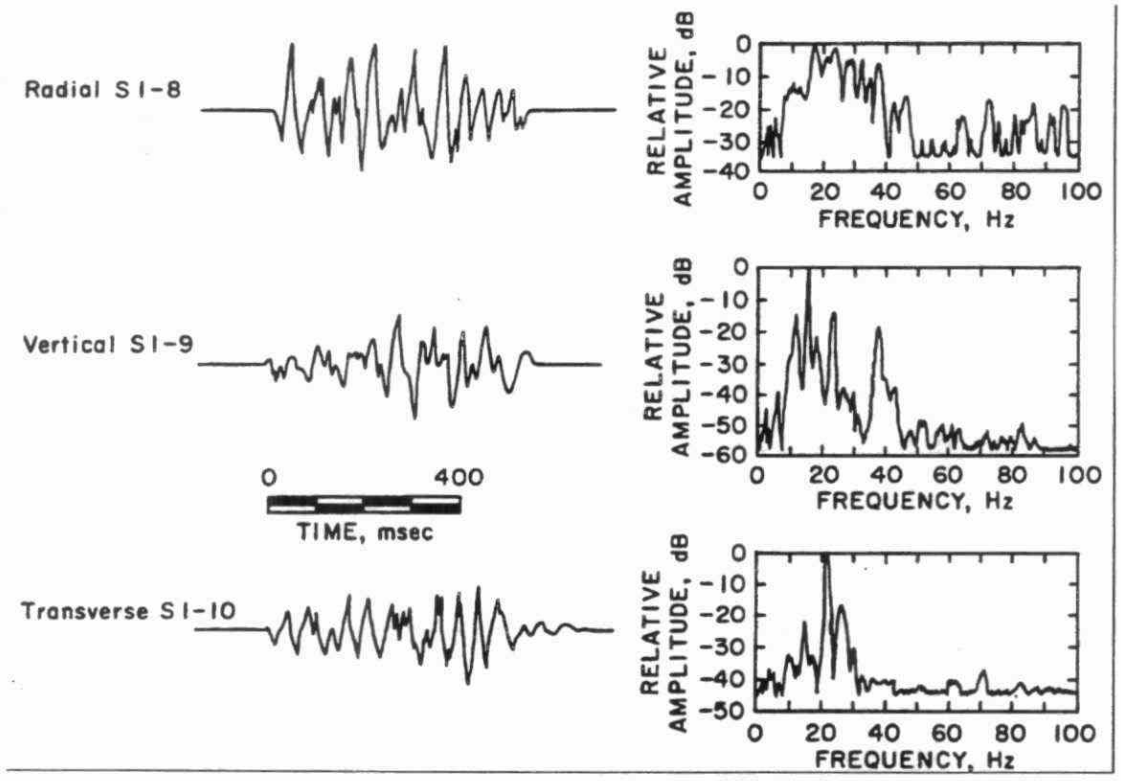



**Figure 7.1 Typical Quarry Blast Time Histories and Spectra**

Two basic parameters used to measure vibration magnitude, related to the movement of the particles of earth through which the pressure pulse propagates are:

- Velocity; how fast the particles move when they are oscillating. Since the velocity is continually changing, the peak or maximum velocity is the useful value that describes the magnitude of the motion. The Peak Particle Velocity is expressed in mm/s.

- Frequency; the number of particle oscillations per second under the influence of the vibration wave is called the frequency and is expressed in Hz. Different types of vibration waves have different characteristic frequencies that depend on many factors. The frequencies of the ground vibration

produced by the blast, that may cause annoyance and/or structural damage, are normally between 3 and 100 Hz.

For a periodic vibration signal, vibration velocity $v$ is expressed as:

$$v = 2\pi fd$$

where f is frequency in Hz,
d is displacement (i.e. the distance that the particles move when they are oscillating).

The amplitude, frequencies and duration of ground vibration change as they propagate because of (a) interaction with various geological media and structural interfaces, (b) spreading out of the wave-train through dispersion, and/or (c) absorption, which is greater for higher frequencies.

Close to the blast the vibration character is affected by factors of blast design and site geometry.

At large distances, the factors of blast design become less critical and the transmitting medium of rock and soil overburden dominate the wave characteristics.

## 1.2 VIBRATION PREDICTION

In the case of "bench blasting", typical for mine or quarry operation, holes are drilled in rows parallel to the "face" and explosive charges are placed in the holes. Detonation of charges is carried out with a certain time delay between holes and between the rows in order to minimize the superposition of blast pulses radiated from each hole. Specific parameters of blast design are shown in Figure 7.2.

The Peak Particle Velocity depends on the maximum charge-weight-per-delay, and not on the total charge weight, providing the delay interval is 8 milliseconds or more.

The results of research studies, combined with the large number of field measurements, have shown that the Peak Particle Velocity from a quarry or a surface mine is a function of a Square Root Scaled Distance (SRSD) expressed as:

$$SRSD = \frac{D}{\sqrt{W}}$$

where D is the distance from the blast to the receptor (in m).
W is the maximum weight of explosive (charge) per delay (in kg).

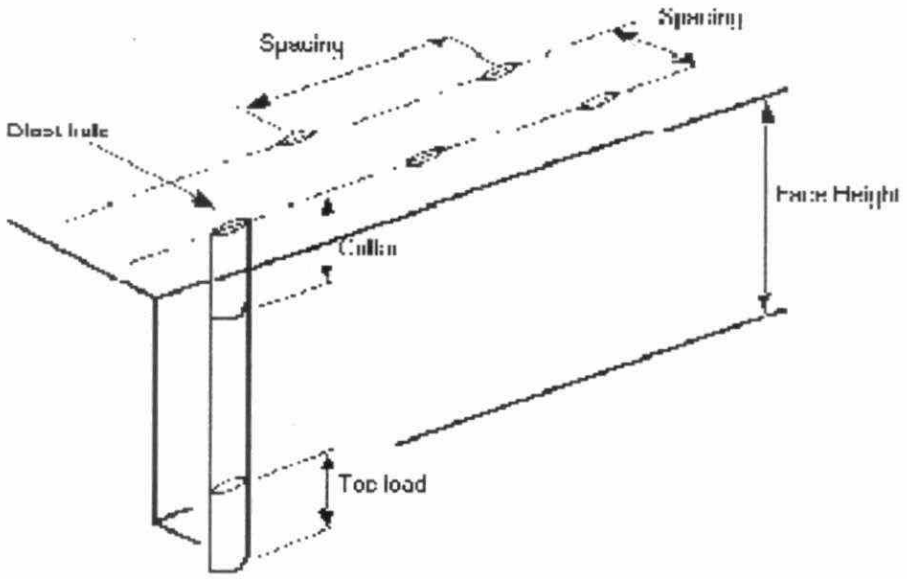



**Figure 7.2 Parameters of Blast Design**

The magnitude of vibration expressed in terms of Peak Vibration Velocity can be predicted from Figure 7.3.

Example

D = 600 m

W = 20 kg

$$SRSD = \frac{D}{\sqrt{W}} = \frac{600}{\sqrt{20}} = 134.16\ m/kg^{\frac{1}{2}}$$

From Figure 7.3, the Peak Vibration Velocity = $4.5 \times 10^{-4}$ m/s = 0.45 mm/s

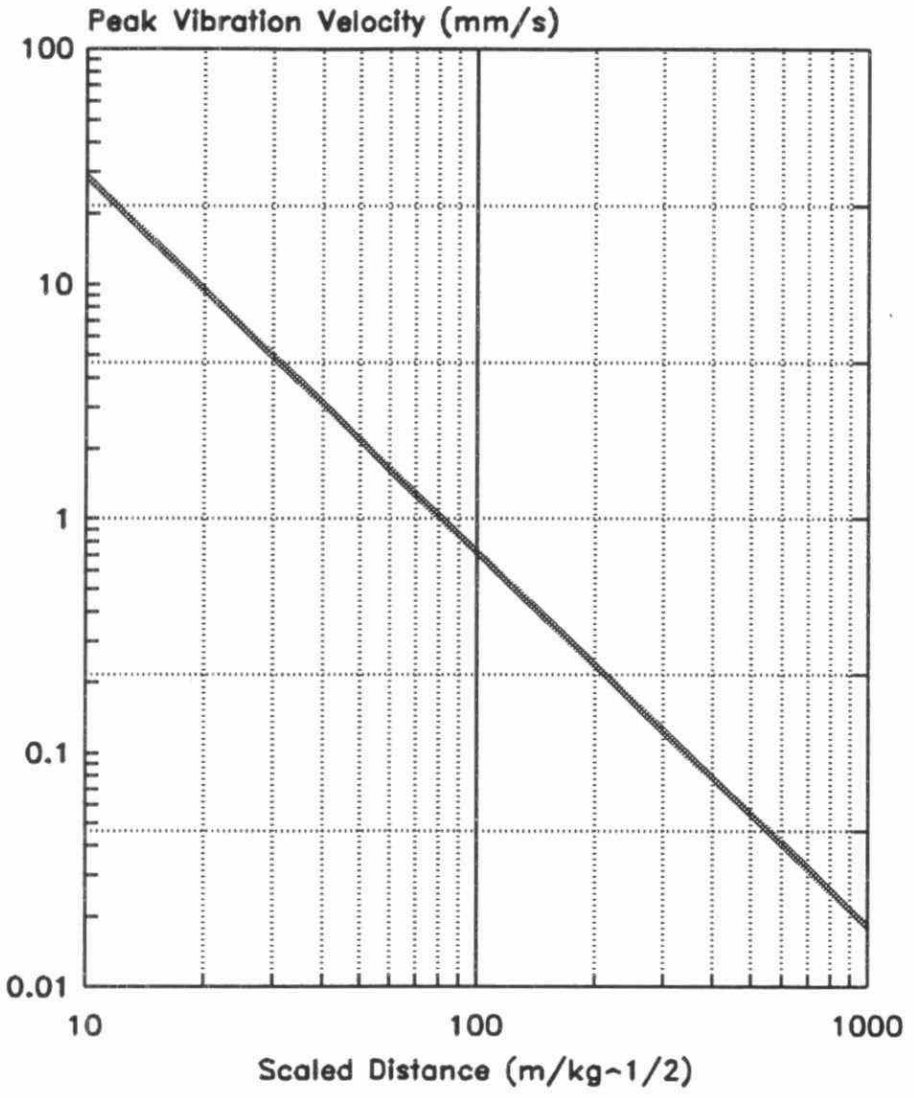



**Figure 7.3 Blasting Vibration Prediction: Peak Vibration Velocity**

It should be emphasized that the prediction model relating the Peak Particle Velocity, charge-weight-per-delay, and distance provides typical values only for planning of blasting projects in the absence of seismic data. Modification may be required when the job started and seismic data are available.

## 2. SOUND (OVERPRESSURE) PRODUCED BY BLASTING

### 2.1 GENERATION AND PROPAGATION

An explosion at or close to the ground surface produces a compressional wave in air, i.e. sound. The amount of sound resulting from a quarry blast (often referred to as overpressure) depends on a number of

factors including the depth of the explosion below the surface, proximity to the free face, confinement of explosive and the type/nature of the surrounding material.

Four causes of air blast overpressures are generally recognized:

- direct rock displacement at the face;
- vibrating ground;
- gas escaping from the detonating explosive through the fractured rock;
- gas escaping from the blown-out stemming.

For example, improper confinement, i.e. plugging of the drill hole (stemming) which holds the explosive, or cracks in the free quarry face will result in substantial increase in the sound level.
Air blast wave will consist of energy over a wide range of frequencies.

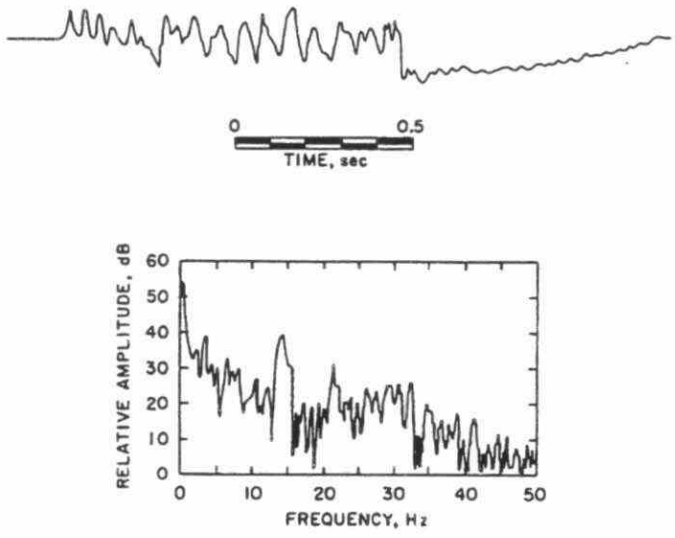
Noise is the portion of the energy of the air blast contained in the audible range from 20 to 20,000 Hz. The portion of energy below the audible range (less than 20 Hz) is known as concussion.

When an air blast wave passes a given receptor location, the pressure of the air at this point rises rapidly to a value above ambient pressure, and then falls more slowly to a value below, before returning to the ambient value.

There are, basically, two types of air blast waves:

- type 1 shown in Figure 7.4 (a), typically encountered in front of the face;
- type 2, shown in Figure 7.4 (b), typically encountered at locations behind the face.

(a) Type 1 airblast: typical of locations in front of the quarry face




(b) Type 2 airblast: typical of locations behind the quarry face

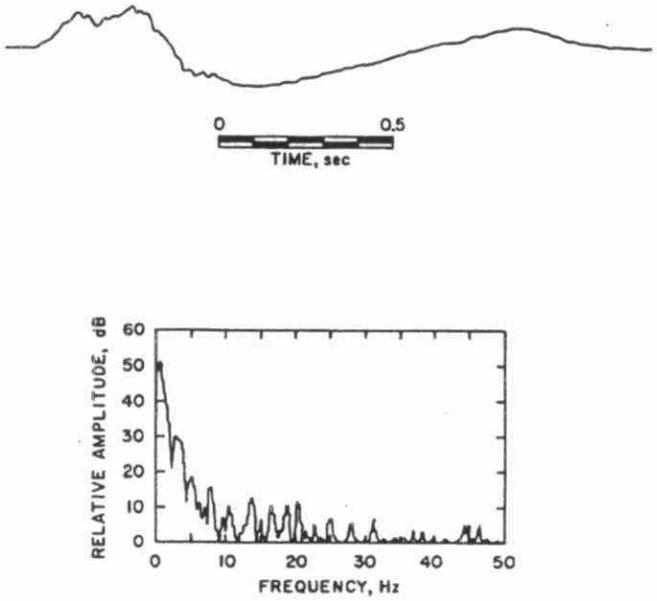



**Figure 7.4 Typical Airblast Time Histories and Spectra**

The maximum excess pressure in the air blast wave is known as Peak Overpressure. The value of the Peak Overpressure can be converted into the Peak Overpressure Level which is expressed in decibels (dB).

## 2.2 PROPAGATION

Atmospheric conditions may affect the intensity of noise from an air blast at a distance. These conditions determine the speed of sound in air at various altitudes and directions. The way in which air overpressure travels can be illustrated by rays which are drawn to be always at right angles to the overpressure wave-front. A "normal" atmosphere where the air overpressure decreases steadily in all directions is shown in Figure 7.5 (a).

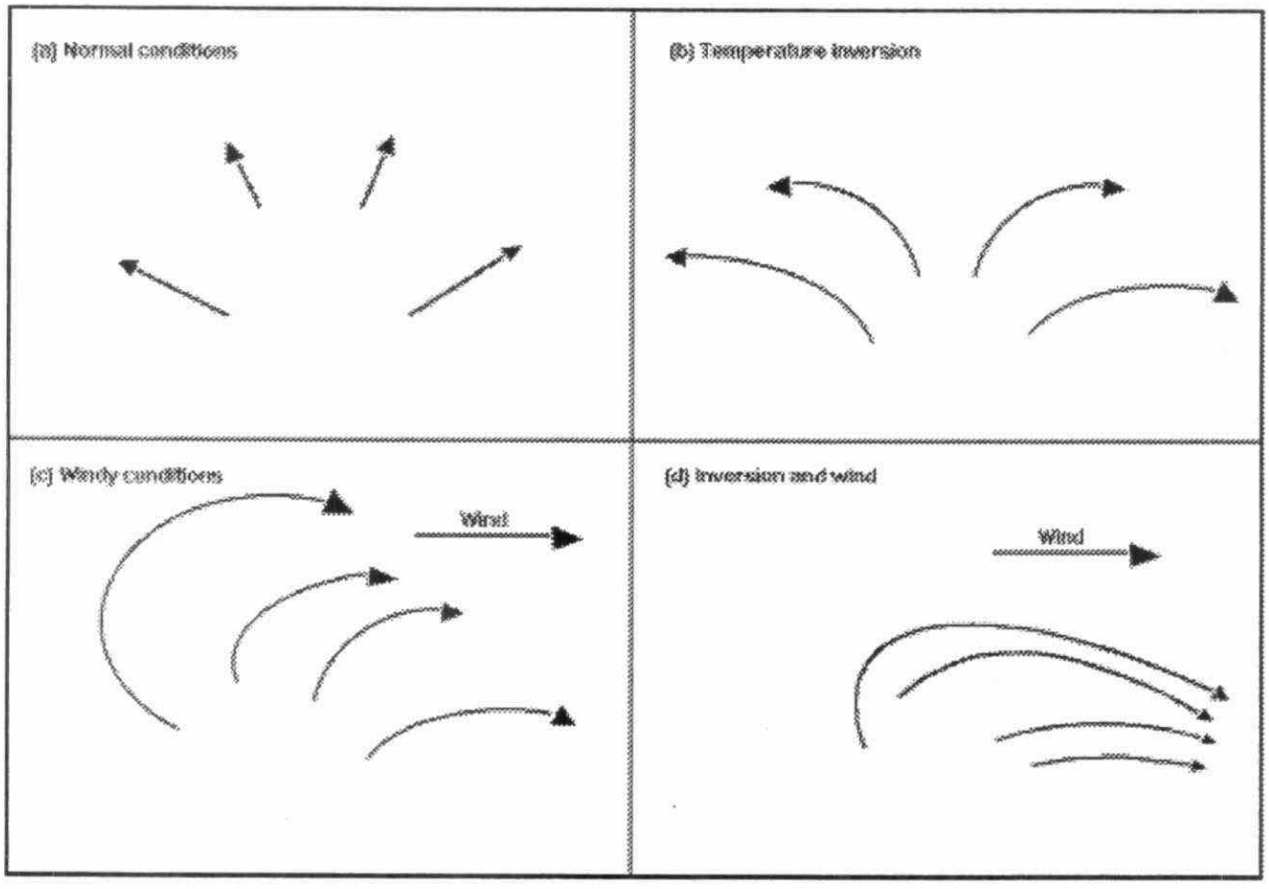



**Figure 7.5 Airblast (Sound) Propagation**

Figure 7.5 (b) shows how a temperature inversion can reflect the rays back towards the ground surface and, as a result, increase the overpressure intensity. Figure 7.5 (c) shows the most commonly found effect, that of wind. The air blast wave-front will be bent in the direction in which the wind is blowing, resulting in an increased sound pressure level downwind and reduced sound pressure level upwind.

If both temperature inversion and wind are present, a condition could exist as illustrated in Figure 7.5 (d) where focussing of the rays occurs downwind. Air blast effects could be severe at and around the focal point while absent closer toward the blast.

## 2.3 PREDICTION OF SOUND (CONCUSSION) PRODUCED BY BLASTING

The Peak Sound Pressure Level of air blast is the function of the Cube Root Scaled Distance (CRSD) expressed as:

$$CRSD = \frac{D}{\sqrt[3]{W}}$$

where D is the distance from the blast to receptor (in m).
W is the maximum weight of explosive (charge) per delay (in kg).

The magnitude of the Peak Overpressure is generally expressed in terms of the Peak Sound Pressure Level. For receptor locations behind and in front of the quarry face, the Peak Sound Pressure Level can be predicted from Figure 7.6.

Example D = 600 m The receptor is located behind the quarry face
W = 20 kg

$$SRSD = \frac{D}{\sqrt[3]{W}} = \frac{600}{\sqrt[3]{20}} = 221.04\ m/kg^{\frac{1}{3}}$$

From Figure 7.6, the Peak Sound Pressure Level = 117 dBLin

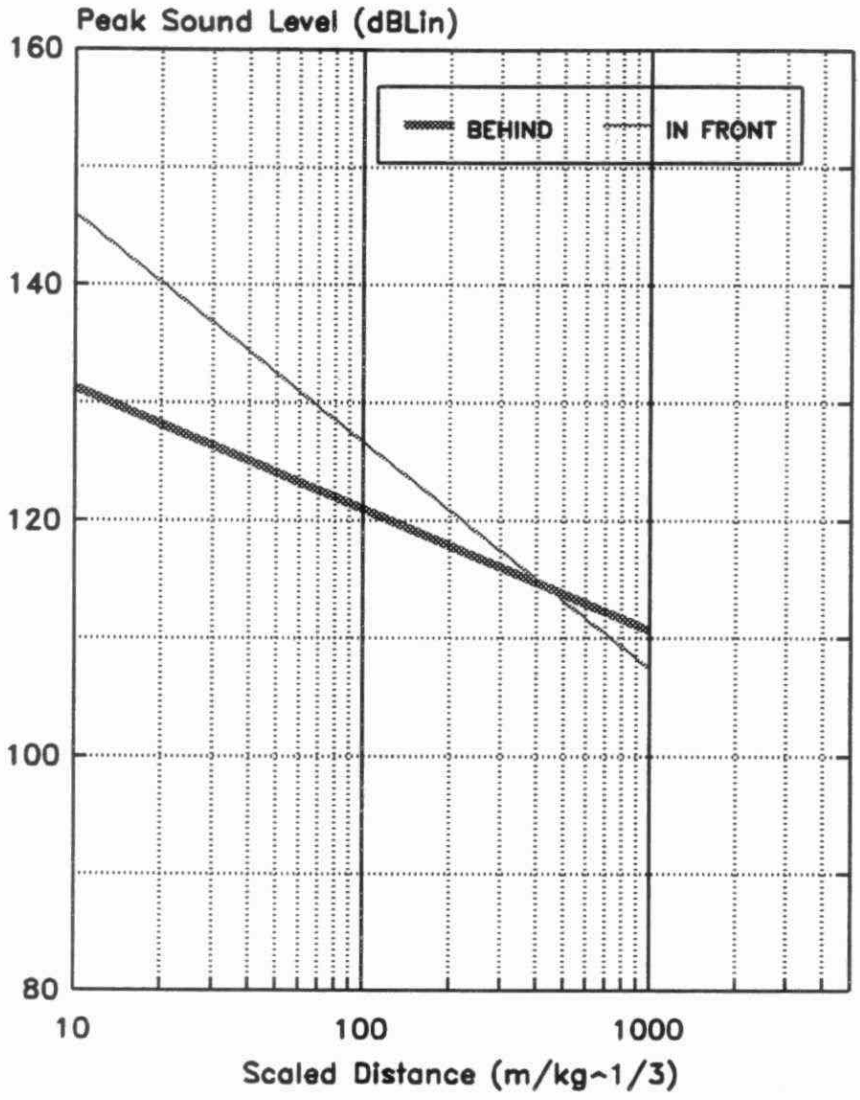



**Figure 7.6 Blasting Noise Prediction: Receptor Behind and in Front of the Face**

## 3. EFFECTS OF BLASTING NOISE AND VIBRATION

### 3.1 BACKGROUND

Blasting operations at quarries and surface mines generate noise and vibration impact of a type quite different from that of transportation, industry and other high level environmental noise and vibration sources. Impact due to blasting is impulsive, relatively infrequent, often unpredictable in time of occurrence and is likely to be quite variable in level. A community may experience such exposure many times over a long period of time, sometimes in residences even at considerable distances from the blasting site.

When blasting operations commence in a settled area, occupants of surrounding dwellings naturally become acutely aware of the blasting sound and, in particular, the vibration of the building. Cracks in walls or foundations are commonly reported following the onset of blasting. Although blasting can result in damage, the inference that cracks are a result of the blasting is frequently incorrect; people generally do not appreciate the fact that the threshold of human perception of vibration is far below the threshold of structural damage.

Blasts may affect communities not only through the shaking of the structural elements of their residences, but directly through the auditory system causing surprise, startle, fear of damage or injury or other secondary effects. Adverse community reaction to blast produced vibration can be expected at levels that are much lower than the thresholds established for structural damage. The technical problems of quantifying community response to blasting events and setting applicable limits are complicated by the simultaneous presence of both air blasts and ground vibration, and many secondary effects such as window or dish rattling.

## 3.2 STRUCTURAL DAMAGE

The parts of a structure that are normally most sensitive when subjected to blasting sound (overpressure) and/or vibration are windows and plastered walls and ceilings. The airborne sound, in addition to the groundborne vibration, may be a concern because blasts contain significant energy in the low frequency range; such sound produces structural vibration, particularly in light-weight structural components such as windows.

Considerable amount of technical research has been performed to identify the limits of potential damage to structures subject to various shocks including quarry (or surface mine) blasting. In comparison to events such as earth quakes, quarry blasting has a much lower damage potential because the earth quakes contain energy at very low frequencies, below 1 Hz. The dominant frequencies of quarry blasting lie usually above 10 Hz.

In North America, research has been conducted by many researchers; the United States Bureau of Mines has been particularly active in this area, particularly in the 1970s. The USBM published a number of technical reports dealing with the measurement, prediction and structural damage of blasting vibration and sound. The conclusions and recommendations of this work have been used in the preparation of safe practices and measurement methods.

The MOE has established criteria for blasting noise and vibration based on the results of extensive research carried out by various agencies, in particular the USBM, and the best current understanding of community

reaction to blasting. The criteria are related to the potential onset of superficial structural damage, and the objective of the criteria is to ensure that the blasting does not result in cracks in plaster, drywall, etc.

## 4. MINISTRY BLASTING CRITERIA

Two sets of limits have been established by the Ministry in the Technical Publication NPC-119, Blasting, to assist in effective control of noise and vibration.

- **Cautionary limit**, applicable to operations not subjected to a routine monitoring.

- **Actual limit**, applicable to operations where a routine monitoring of noise and vibration is carried out by the quarry/mining operator.

The limits are expressed in terms of the unweighted or linear Peak Sound Pressure level (dBLin) and peak vibration velocity (cm/s). The following limits are specified:

(i) Concussion - cautionary limit: peak pressure level of 120 dBLin;

(ii) Concussion - actual limit: peak pressure level of 128 dBLin;

(iii) Vibration - cautionary limit: peak vibration velocity of 1 cm/s;

(iv) Vibration - actual limit: peak vibration velocity of 1.25 cm/s.

A detailed procedure for the measurement of sound and vibration due to blasting operation is described in Section 5 of the Technical Publication NPC-103, Procedures.

## 5. MONITORING INSTRUMENTATION

The equipment for monitoring blast noise and vibration consists of a microphone and a seismic transducer; the instrumentation is capable of detecting and recording the peak sound pressure level and the peak vibration velocity in three mutually perpendicular directions. When taking the velocity measurements, the three perpendicular measurements usually are: two in a horizontal plane, one oriented towards the blast, recording the radial or longitudinal ground motion, and the other at right angles, recording the transverse motion. The third measurement is in the vertical direction, recording the vertical ground motion.

Modern blast monitors are designed for the automatic, unattended field recording of three channels of seismic data and one channel of sound pressure signals. In automatic operation, seismic and acoustic data are continuously sensed, amplified and entered into a four-channel memory system. When a seismic event exceeds a pre-determined "trigger level", the recording circuitry is turned on and data from the four channels including the triggering event are recorded.

The monitor usually provides the digital display of the Peak Particle Velocity and Peak Sound Level associated with the event, the date and time, as well as range during recording. Some monitors offer printouts of the full waveform of the ground vibration and the sound pressure signals with detailed annotations, and automatic calibration.

The monitor is usually provided with an outdoor microphone, weatherproofed for all weather exposure with mounting accessories and connection cables.

## 6. MINIMIZING BLAST NOISE AND VIBRATION IMPACT

There are several steps an operator can take to reduce noise and vibration impact due to blasting.

### 6.1 FACTORS IN THE DESIGN OF THE BLAST

- Use reduced charge-per-delay by reducing hole depth and diameter, sub-divide explosive charges in hole.
- Use sequential blasting.
- Avoid the use of unconfined explosives.
- Use adequate stemming.

### 6.2 BLAST SCHEDULING

- Schedule blast at times when neighbours are normally busy or expect blasting to occur.
- Avoid early morning or late afternoon blast to reduce possibility of blasting during temperature inversions.

### 6.3 CONSIDERATION OF FAVOURABLE WEATHER CONDITIONS

- Avoid blasting during foggy, hazy or smoky days with little or no wind. These are conditions typical of temperature inversion.
- Avoid blasting during strong winds accompanying passage of a cold front.

- Avoid blasting during periods of the day when surface temperature is falling.
- Do not blast too early in the morning or after sunset on clear days with very light winds.
- Do not blast on cloudy days with a low ceiling, especially when there is little or no wind.

## 6.4 PUBLIC RELATION AND EDUCATION

- Reduce startle effect by providing a warning signal prior to blasting.
- Blast at the same time of the day.
- Invite neighbours for a site visit.
- Return call regarding complaints.
- Investigate damage claims.
- Compensate for proven losses or damages.

## APPENDIX 8. BUILDING ACOUSTICS

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Understand the concepts of transmission loss (TL), sound absorption and sound transmission class (STC)

2. Know the STC rating of typical walls, windows and doors

3. Understand the techniques of improving the STC rating of walls, windows and doors

## BUILDING ACOUSTICS

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# BUILDING ACOUSTICS

## 1. BASIC ELEMENTS OF NOISE CONTROL

Successful control of indoor noise originating from outdoor sources depends on understanding the behaviour of the interaction between sound waves and the materials with which they come into contact.

Two main factors affecting this interaction are the transmission of sound energy through a material and the absorption of energy at, or in the vicinity of, the material's surface. It is important to distinguish between these two factors because they are related to different physical properties of the material. The former determines how much sound energy passes through the wall and enters the room. Once in the room, the energy is further reduced by absorption, i.e. the action of the absorbents (these may also be carpeting, furnishings, etc.) which determine the final sound level in the room.

### Sound Transmission

When sound waves encounter a panel such as a wall or window, the vibration of the air causes the panel to vibrate and some of the incident energy is reflected. The vibrating panel sets the air on its opposite side into vibration. As a result, the energy transmitted through the panel appears on the other side as sound waves of reduced intensity.

### Sound Absorption

The absorption of sound waves occurs at the surface of the panel. When sound waves are incident upon the surface of a panel, air flows in and out of the pores in the material due to the pressure changes produced by the sound. Resulting frictional forces convert the sound energy into heat although the amount of dissipated energy is very small. The total amount of incident sound energy reflected by the wall is thus reduced, lowering in turn the reflected sound level.

### Noise Reduction

A term that describes the combined action of these two effects is "noise reduction", which is defined as the difference in sound level between the exterior and the interior of the building, regardless of the mechanism of the reduction.

## 2. SOUND TRANSMISSION LOSS AND STC RATING

### 2.1 SOUND TRANSMISSION LOSS

The measure of a material's ability to attenuate the passage of sound is the sound transmission loss. By definition the Sound Transmission Loss, TL, is the ratio, expressed in dB, of the airborne sound power incident upon the panel to the sound power transmitted by the panel and radiated on the other side. A panel having a high transmission loss would make a good insulator; a panel with a low transmission loss would be a poor insulator.

The Sound Transmission Loss of a panel is dependent on the frequency of the sound, the angle of incidence of the sound wave upon the panel and the mass and stiffness of the panel. Analysis of the entire sound transmission loss frequency curve of a given panel provides the best method for evaluation of its sound insulating properties. Such a detailed procedure is usually not needed for many assessments in land use planning. A simpler method of rating partitions by a single number can be used.

This single number rating is a good means of comparing the performance of different panel constructions tested under identical (or nearly identical) conditions. The number is assigned by the testing laboratory according to a carefully defined procedure and is a fairly reliable measure of comparative acoustic performance between different panels. This number is called the Sound Transmission Class (STC) of the panel or material. The detailed procedure is given, for instance, in ASTM Standards E-90, E-336 and E-413.

### 2.2 STC RATING

To determine the STC of a test panel, the Sound Transmission Loss values, as determined in the sixteen 1/3 octave bands with centre frequencies in the range of 125-4000 Hz are compared with the values of STC reference contour, shown in Figure 8.1. Also refer also to ASTM E-413.

Comparison is made according to the following conditions:

- A single unfavourable deviation (i.e. a value below the contour) may not exceed 8 dB.
- The sum of the unfavourable deviations shall not be greater than 32 dB.

The STC for the panel is the numerical value which corresponds to the Transmission Loss value at 500 Hz of the highest contour for which the above conditions are fulfilled. Figure 8.2 presents an example in which the resultant STC rating of a partition is STC-45.

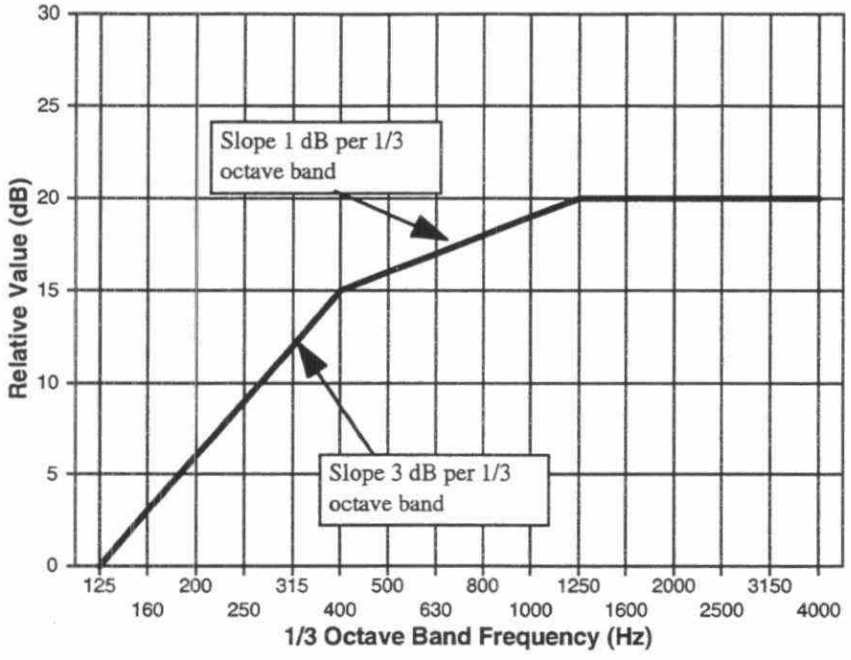


**Figure 8.1: Sound Transmission Class (STC) Reference Contour**

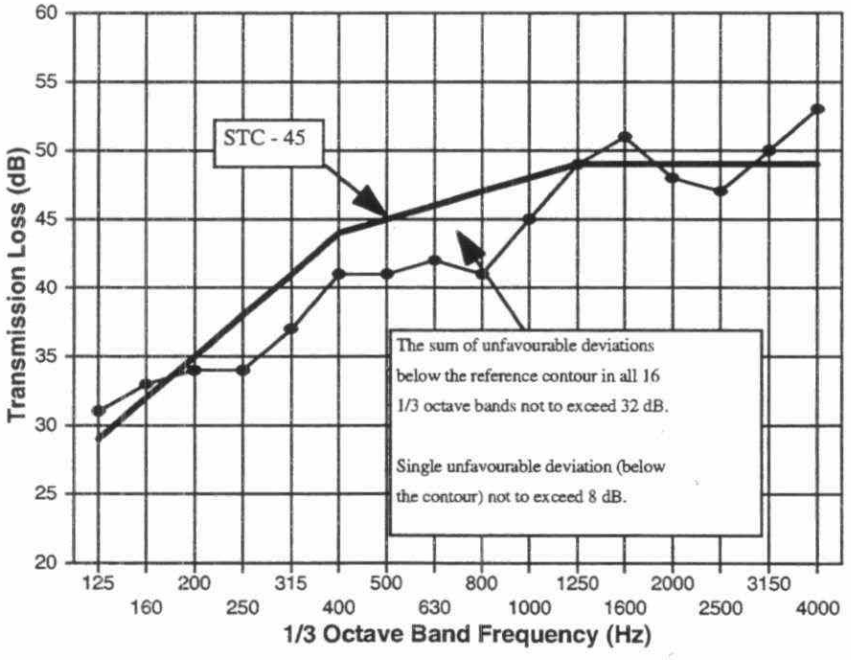


**Figure 8.2: Determination of the STC Value Rating of a Partition: STC-45**

## 3. SOUND TRANSMISSION CHARACTERISTICS OF MATERIALS

Several factors influence the sound transmission characteristic of a material: mass per unit area of the panel, its stiffness, frequency of incident sound and angle of incidence.

For a limp mass (i.e. material that lacked stiffness) the sound transmission is directly proportional to mass and frequency. Assuming random incidence of sound, the transmission loss of a panel can be expressed by:

$$TL = 20 \log (f\,m) - 47$$

where $f$ = the frequency in Hz

$m$ = surface mass density of a panel in $kg/m^2$

This equation implies that for a doubling of either the frequency or the mass, the transmission loss increases by 6 dB. This is known as the "mass law". However, a panel usually behaves in a more complex manner, depending upon its stiffness. Figure 8.3 shows a typical sound insulation curve for a single panel.

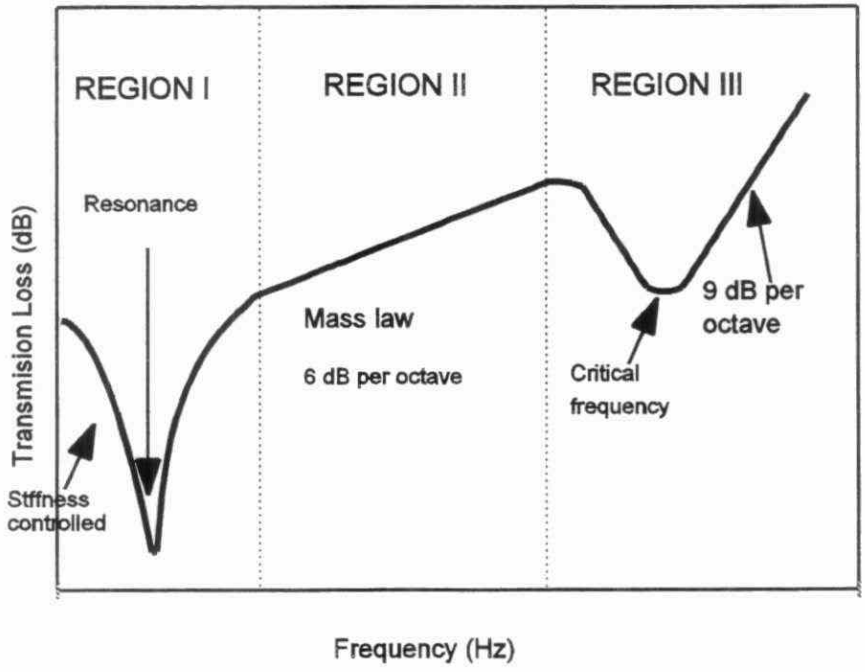


**Figure 8.3: Typical Sound Insulation Curve**

The curve is broadly divided into three regions. In Region I (the low frequency range) the sound transmission of the panel is stiffness controlled at first and then fluctuates due to resonance effects. These

resonance effects depend on panel size, mass, stiffness and on the method of fixing at the edges. In most cases, the size and material of the panel are such that the resonance frequency is well below the lowest frequency of interest.

In Region II the sound transmission is primarily mass controlled (mass law) and the rate of increase is 6 dB per octave theoretically, but about 4.5 dB per octave in practice.

In Region III a marked drop in sound transmission loss may occur due to the so-called "coincidence effect" which occurs when the bending wave in a panel is in phase with an oblique wave front of the incident sound. This happens at some frequencies and at some angles of incidence with nearly all materials.

The lowest frequency corresponding to grazing incidence, at which the coincidence effect occurs is called the critical frequency. In general, the coincidence effect may affect sound transmission loss of a panel more seriously than resonance (occurring in Region I) because it can occur well within the 100 Hz - 4000 Hz range.

## 4. SOUND TRANSMISSION THROUGH COMPOSITE STRUCTURES

In a general case, the panel may be a wall with a door and windows and may even be built in several sections each with a different transmission loss because of different construction. The sound transmission loss of such a composite structure depends on the relative areas and transmission losses of its components.

### 4.1 SOUND TRANSMISSION COEFFICIENT

To find the average transmission loss of the entire assembly, an average transmission coefficient, $t_s$, has to be first determined. The amount of sound power passing through a building panel component is proportional to the product of the area and sound transmission coefficient.

For a multi-component wall system, the transmission coefficient is given by:

$$t_s = \frac{(t_1S_1 + t_2S_2 + t_3S_3 + \ldots)}{S}$$

where $S$ is the total area of the wall

$t_s$ is the effective sound transmission co-efficient of the whole wall

$t_1, t_2, t_3 \ldots$ are the sound transmission coefficients of the wall components

$S_1, S_2, S_3 \ldots$ are the areas of the wall components.

The following is a relationship between the sound transmission loss and sound transmission coefficient:

$$TL = 10 \log (1/t_s)$$

Figure 8.4 presents a graph the calculation of the composite insulation of a two component wall. The importance of each component is determined by its individual sound transmission loss (attenuation) together with its surface area. Therefore, the main concern in the majority of houses are the windows because they occupy a large surface area and because they have low sound transmission loss.

While the curves in Figure 8.4 can be used only for a wall with not more than two different TL section, a composite wall with more than two elements can be treated taking an additional section at a time as long as one remembers to use the previous composite TL at each step.

## 4.2 EFFECT OF GAP UPON TRANSMISSION LOSS

Figure 8.4 may also be used to estimate the effect of gaps, cracks and openings on the transmission loss of doors, windows, etc. If the total area of the opening is known, the opening can be considered as the weak component with a sound transmission loss of zero dB.

It can be seen that even small openings reduce the sound transmission by a significant amount, especially for high sound transmission losses of the component. Suppose, for example, that a crack is left in a wall; the area of the crack constituting 1.0% of wall area. For a wall having TL of 45 dB, the crack will reduce the composite transmission loss TL by 25 dB to 20 dB.

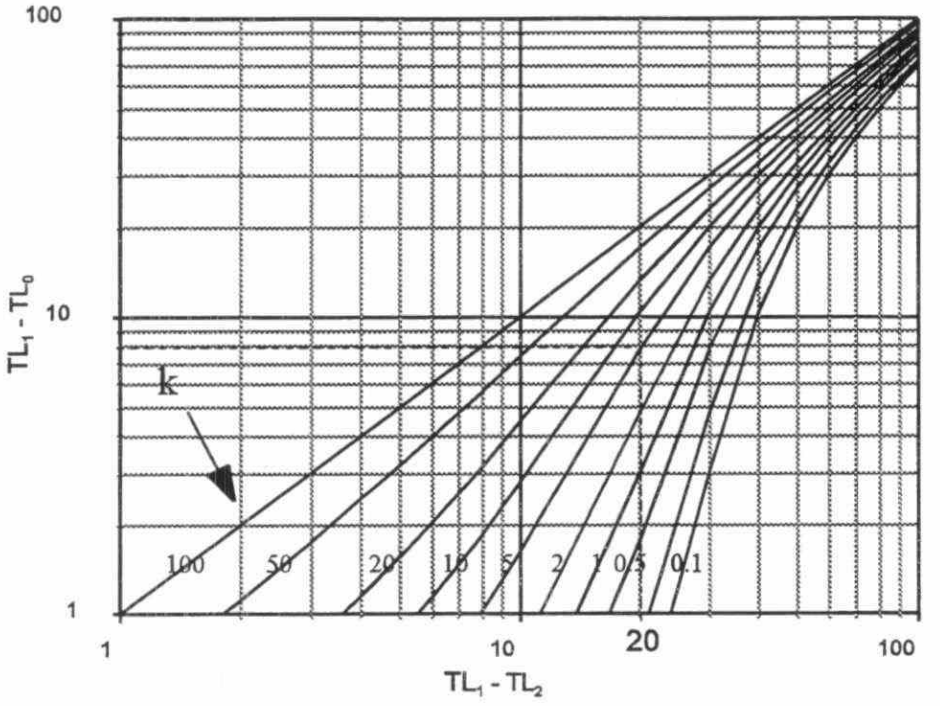


**Figure 8.4: Effective Transmission Loss of a Composite Wall**

| | | |
|---|---|---|
| $TL_0$ | = | sound transmission loss of combination wall |
| $TL_1$ | = | sound transmission loss of plain wall alone |
| $TL_2$ | = | sound transmission loss of window alone |
| k | = | percentage of all area occupied by window |

Example:

| | | | |
|---|---|---|---|
| Transmission loss of wall | $TL_1$ | = | 50 dB |
| Transmission loss of window | $TL_2$ | = | 30 dB |
| Area % of window/wall | k | = | 5% |
| | | | |
| Transmission loss difference | $TL_1 - TL_2$ | = | 20 dB |
| then from graph | $TL_1 - TL_0$ | = | 8 dB |
| Transmission loss of combination | $TL_0$ | = | 50 - 8 dB = 42 dB |

## 5. STC RATING OF BUILDING COMPONENTS

### 5.1 STC RATING OF CONVENTIONAL WALLS

Different wall materials and designs vary greatly in their sound insulating properties. Figure 8.5 shows wall types ranging from the lowest to the highest sound insulation values.

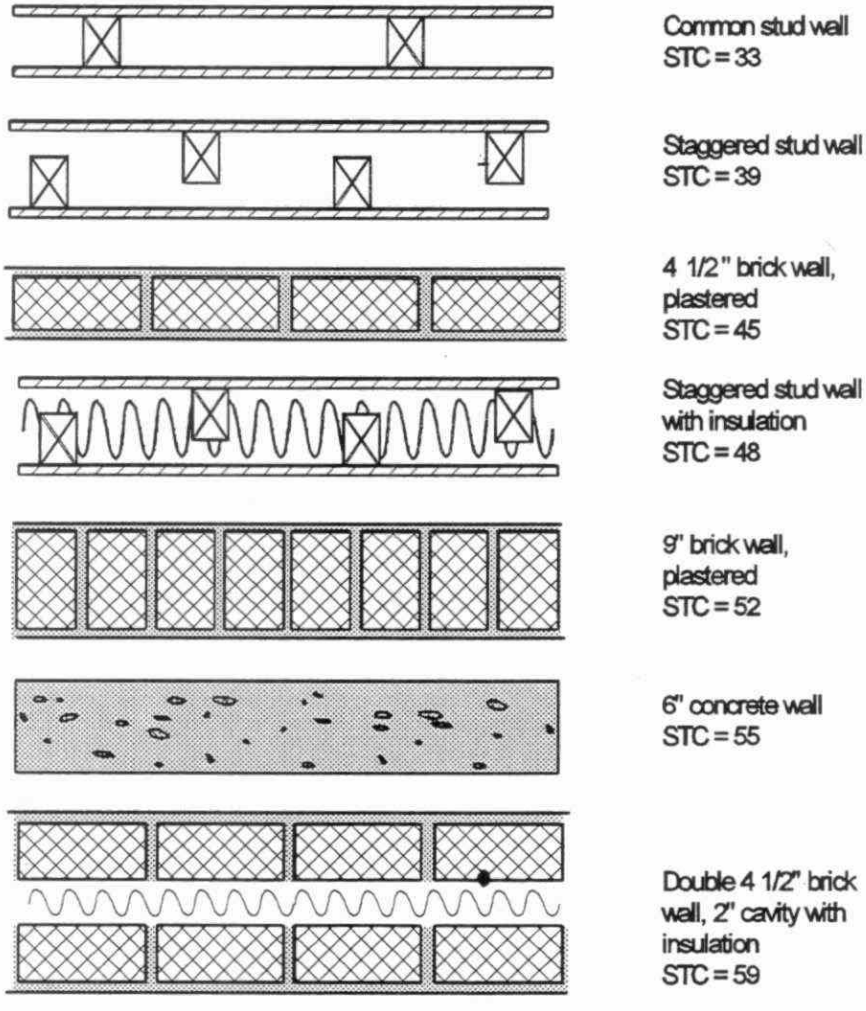


**Figure 8.5: STC Rating of Common Walls**

## 5.2 METHODS TO IMPROVE STC RATING OF WALLS

### 5.2.1 Effect of Increased Mass and Stiffness of the Wall

In general, the denser the wall material the more it will reduce noise. Thus, concrete walls are better insulators than wood walls of equal thickness. Increasing the thickness of a wall is another way to increase mass and improve sound insulation. Doubling the thickness of a wall can result in as much as 6 dB reduction in noise level. However, the costs of construction tend to limit the feasibility of large increases in wall mass.

The relative stiffness of the wall material can influence its sound attenuation value. Care must be taken to avoid wall construction that can vibrate excessively at audible frequencies and transmit exterior sound to the indoor areas.

### 5.2.2 Use of Cavity Walls

A cavity wall, composed of two or more layers separated by an airspace, results in a more effective sound insulator than a single wall of equal weight.

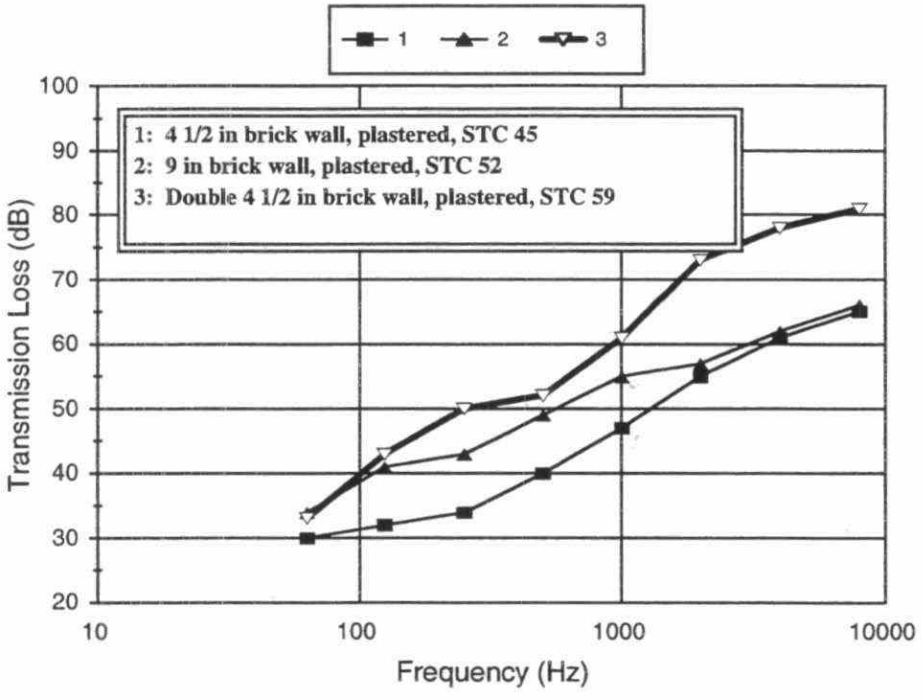


**Figure 8.6: Transmission Loss of Cavity Wall vs. Single Layer Wall**

For example, if single layers of 4 ½ in brick were used to make two walls, 4 ½ in and 9 in thick, weighing approximately 250 kg/m$^2$ and 500 kg/m$^2$, the transmission loss curves would look like the lines 1 and 2 shown on Figure 8.6. If the 500 kg/m$^2$ wall were in two separate layers spaced about 50 mm (2 in) apart, the transmission loss would be would be significantly higher, line 3 in Figure 8.6.

Increasing the width of the air space results in higher transmission loss values for a given wall. A 50 mm air space provides significant value but increasing the spacing to 150 mm would increase the TL by an additional 5 dB or so. However, extremely wide continuous air spaces are difficult to design into walls, and the ultimate reduction potential is limited.

### 5.2.3 Increased Spacing Between Studs and Use of Staggered Studs

Double walls of wood or metal section frame construction may include split or staggered studs. In such construction the air, by virtue of its compressibility, acts as the spring element or vibration isolator. A wider air space provides a softer spring action which results in greater sound insulation.

Also, the increased spacing between studs reduces excessive coupling between the two walls and results in a reduction of acoustic energy transmitted through such a structure. For example, in a common stud wall construction, a 61 cm (16 in) stud spacing gives a 2 to 5 dB increase in STC over the common 41 cm (16 in) spacing. Sound transmission loss can be increased further by attaching each stud to only one panel and alternating between the two panels. See Figure 8.5.

### 5.2.4 Use of Sound Absorbent Liners

Also known as insulation blankets, these can increase sound attenuation when placed in the air space of a double wall. Sound absorbent liners tend to minimize the sound energy build-up in the hollow reverberant wall cavities, particularly at the higher frequencies, as well as minimize the effect of leaks.

Made from sound absorbing materials, such as mineral or rock wool, fibreglass, hair felt or wood fibres, sound absorbent liners can improve wall performance by as much as 10 dB.

They are effective in relatively lightweight frame construction and in heavy masonry construction if the structural transmission is not excessive. However, the use of insulation blankets in airspaces of common stud walls contribute little toward improved sound insulation. Owing to the rigid ties of the stud framing to the wall surfaces, the entire wall behaves like a diaphragm under vibration excitation and transmits the sound readily; thus the effectiveness of the insulation blanket is "short circuited".

Sound absorbent liners are also heat energy insulators and their use should be encouraged wherever possible as a conservation measure.

### 5.2.5 Use of Resilient Materials and Dissimilar Panels

Any rigid coupling between two walls of double panel construction will lower its ability to reduce the amount of the transmitted energy. Panels made up of resilient layers such as fibre board, glass fibre board, resilient clips as well as semi-resilient attachments are simple to insert and are relatively inexpensive. Their use can raise the STC rating of the assembly by 2 to 5 dB.

**Figure 8.7: Use of Resilient Clips**

If the leaves are made of different materials and/or thicknesses, the sound reduction qualities of the wall are also improved.

### 5.2.6 Proper Sealing and Installation of Walls

If the sound insulation of a high performance wall is to be realized, the wall must be of "air tight" construction and well sealed at the perimeter. Care must be exercised to seal all openings, gaps, holes, joints and penetration of piping. Even hairline cracks which might occur, particularly at the adjoining wall, floor and ceiling edges, during the drying out period or building settlement should be re-sealed.

A substantially greater amount of sound energy is transmitted through a crack than would be normally expected on the basis of its area, as illustrated in Figure 8.4.

Also, proper installation of the wall requires that one should try to keep coupling or rigid ties to other structural assemblies at an absolute minimum. The purposes of decoupling the wall is to break up, or minimize, the sound flanking paths transmitted through the structure from outside or from one room to another.

## 5.3 WINDOWS

Sound is transmitted into a building through acoustically weak components; windows are typically the weakest exterior building components. An acoustically weak window will severely undermine the effect of acoustically strong exterior walls.

For example, if a wall with an STC rating of 45 contains a window with an STC rating 26 covering only 20% of its area, the overall STC of the composite wall will be STC 33, a reduction of 12 dB, see Figure 8.4.

The following techniques can be used to reduce noise transmitted through windows.

### 5.3.1 Closed Windows

The first step in reducing unwanted sound is to close the windows. Although the greatest amount of sound insulation is achieved if the windows are permanently sealed, operable (openable) windows can be designed and manufactured with proper and effective acoustical seals. Such seals (and weatherstripping) are crucial to the acoustical performance of windows.

### 5.3.2 Reduced Window Size

The smaller the window, the greater the net sound transmission loss of the total wall area of which the window is a part. Reducing the window size is used because it precludes the cost of expensive acoustical windows. However, this technique is a limited effectiveness; for example, reducing the window-to-wall proportion from 50% to 20% reduces noise inside by only 3 dB.

Table 8.1 illustrates STC ratings for a composite wall with various percentages of glass area.

The Ontario Building Code requires a certain minimum window-to-wall size ratio: the OBC requires that windows of bedrooms, living rooms and dining rooms must have a glass area which is at least 10% of floor area.

| | Single Glazed Window | | Double Glazed Window | | Special Construction Permanently Sealed Window | |
|---|---|---|---|---|---|---|
| Window STC | 25 | | 30 | | 40 | |
| Wall STC | 35 | 50 | 35 | 50 | 35 | 50 |
| **% Glass Area** | **Combined Wall & Window STC** | | | | | |
| 10 | 32 | 35 | 34 | 40 | 35 | 47 |
| 25 | 30 | 31 | 33 | 36 | 36 | 44 |
| 50 | 28 | 28 | 32 | 33 | 37 | 42 |
| 75 | 26 | 26 | 31 | 31 | 38 | 41 |

**Table 8.1 STC Values for a Composite Wall with Various Percentages of Glass Area**

### 5.3.3 Increased Glass Thickness

Improved sound insulation can be obtained by increasing the weight (i.e. thickness) of the glass since glass reduces noise by the mass law principle. Figure 8.8 shows the variation of the STC value with glass pane

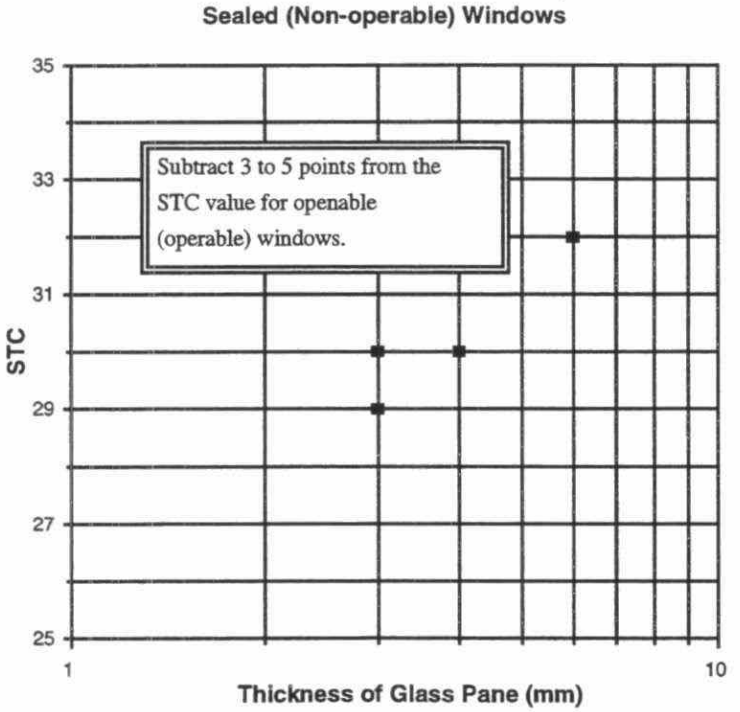


**Figure 8.8: Relationship between STC and Glass Thickness of Single Glazed Windows**

thickness, for single pane sealed (inoperable) windows. The graph shows that the STC increases with glass thickness and that typical 3 mm, 4 mm and 6 mm glass windows have STC values in the range of 29 to 32. Other examples (not on the Figure) indicate that a 12.7 mm (½ in) thick glass can have an STC of 37 and a 19 mm (¾ in) thick glass window can have an STC of approximately 39.

However, increasing the STC of a window by means of an increase in glass thicknesses is generally not practical; double or triple glazed window are more effective. For example, a double pane window consisting of two 3 mm glass panes separated by a 12.7 mm (½ in) air space will have an STC of about 30 depending on the type of seal, frame construction, etc.

A considerable improvement of window insulation can be achieved by laminating a single pane with a thick transparent plastic, which is both noise and shatter resistant. Laminated "sound-retarding" glass is a sophisticated form of safety glass, using multiple layers of thin glass, laminated with layers of plastic to make a monolithic pane, ranging in thickness from about 6.4 mm to over 26 mm. The 26 mm composite glass may well have an STC 40 rating.

### 5.3.4 Double Glazed Windows

Double glazed windows are paired panes, separated by an air space, hung in a special frame. Generally, the performance of the double glazed window may be increased

- increased air space width
- increased glass thickness
- proper use of seals
- slightly dissimilar thickness of the panes
- slightly non-parallel panes

Sound insulation generally increases with increased gap between the glass panes. However, experimental studies of double glazed units have shown that sound insulation approaches a maximum with an optimum spacing of 100 mm and only a small increase occurs thereafter with greater air spacing.

In all double and multiple glazing systems, the sound isolation is increased when the glass panes are mechanically isolated from each other. Where the panes are fixed in separate frames, the frames should be so mounted that vibrations from one cannot be easily transmitted to the other. Furthermore, as for all windows, proper seals and weatherstripping are extremely important.

To further improve the sound insulation between double glazed panes, the panes could be of different thicknesses, different weights and slightly non-parallel to each other. The non-parallel panes is expected to prevent acoustical coupling and minimize resonance effects. The construction of such glazing systems

is usually expensive and, recent studies have shown that slanted windows do not improve the STC over a non-slanted double glazing.

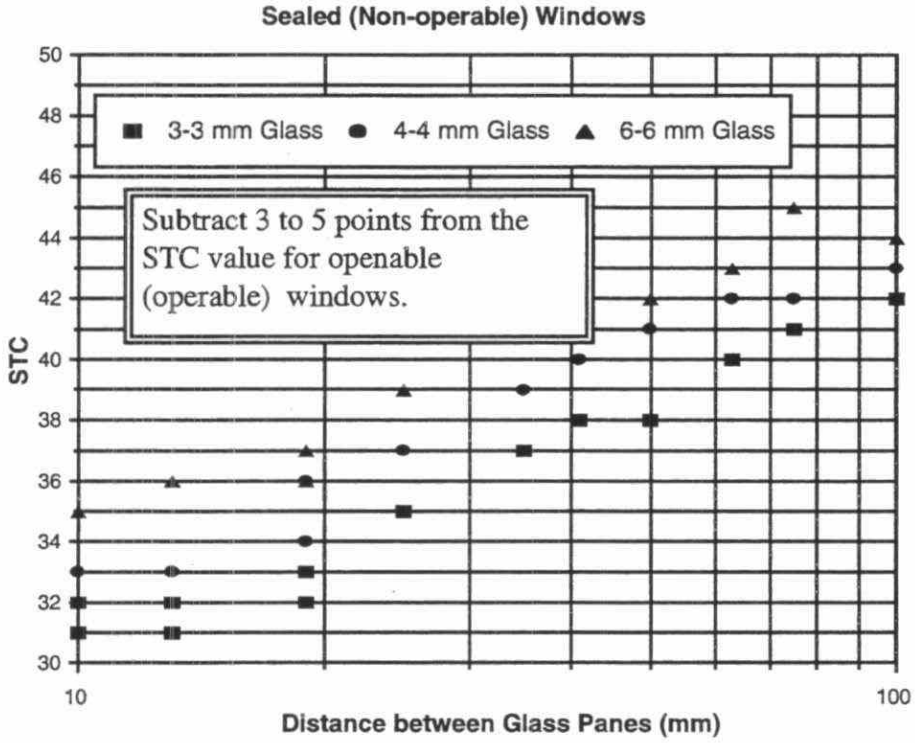


**Figure 8.9: Relationship between STC and Glass Thickness of Double Glazed Windows**

## 5.4 DOORS

The transmission loss of doors obeys the same mass law that holds true for single panels. Generally the greater their density the better their sound insulating properties. However, a good acoustical seal around the edges and insulation in the cavity of a double leaf door are both essential. Improper sealing around the edges of even thick doors will result in poor sound insulation and, therefore, care should be taken that a good positive seal exists between the door frame and the door panel.

Table 8.2 gives the STC rating of typical designs of exterior doors, with and without proper acoustic seals.

| Type of Door | Closed | Acoustic Seal |
|---|---|---|
| Wood, solid core 46 mm, 20 kg/m$^2$ | 30 | 35 |
| Wood, hollow core 46 mm, 6.3 kg/m$^2$ | 20 | 21 |
| Steel, flush pane with foamed-in polyurethane, 16 kg/m$^2$ | 27 | 28 |
| Fibreglass reinforced plastic with foamed-in polyurethane, 12 kg/m$^2$ | 25 | 26 |

**Table 8.2 STC Rating of Doors**

The relatively low sound transmission loss of doors will significantly reduce acoustically stronger walls. For example, the common hollow door taking up 20% of a wall having an STC of 48, will reduce the composite STC of such a wall structure to STC 27.

## 5.5 CEILINGS AND ROOFS

Acoustical treatment of ceilings and roof decks is not usually necessary unless the noise is extremely severe and the sound waves pass over the building roof.

Ceilings are usually considered absorptive systems, while roof decking will provide sound barrier properties since there will generally be a layer of tar, tar paper, gravel or other materials to weatherproof the construction. Various types of roof deck systems come in different thickness and provide a different degree of sound absorption and sound attenuation depending on this thickness and on the type of built up roof-backing used.

## 6. REFERENCES


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## APPENDIX 9. NOISE AND VIBRATION ABATEMENT TECHNIQUES

**OBJECTIVES:**

Upon completion of this topic the trainee will be able to:

1. Describe the concepts of noise and vibration abatement techniques
2. Understand types of noise and vibration control at the source
3. Understand types of noise and vibration control within the transmission path

## NOISE AND VIBRATION ABATEMENT TECHNIQUES

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# NOISE AND VIBRATION ABATEMENT TECHNIQUES

## 1. INTRODUCTION

Once the source of noise has been identified and the sound levels measured, consideration should be given to implementation of engineering or administrative measures to control the noise. Although every noise control problem must be examined individually, there are three separate components in the problem analysis that should always be considered: the source, the propagation path, and the receiver. Acoustical and/or vibration treatment may be applied to any or all of these components with the general order of the precedence as listed, i.e., the most effective solution usually results from noise reduction at or near the source.

As sound is a form of energy, the objective of abatement is to reduce the amount of sound energy generated by the source, divert the flow of sound energy away from the receptor, or to shield the receptor from the sound energy.

There may be several different sources operating, or perhaps a single source displaying several distinct components contributing to the noise. In either case source identification and characterization are necessary for the proper design of abatement measures. If, for example, a source has several modes of operation, it is important to attribute sound pressure levels correctly to each distinct mode.

Some methods of noise abatement are better than others, and in every instance, the best available method should be used. In determining the most appropriate measure or action, the approach to noise abatement must be systematic. The feasible abatement options in order of preference may include:

a) Turning off the noise source.
b) Removal of the noise source.
c) Reduction of noise at source.
d) Screening the noise source.
e) Modification of the noise source.
f) Relocation of the receptor.

Options a), b), and f) represent administrative controls, while options c), d) and e) represent engineering controls. The objective of this chapter is to discuss the engineering controls available in the process of noise abatement. Engineered controls can be applied either to the sound source or transmission path.

## 2. NOISE ABATEMENT AT THE SOURCE

Control of the source emission levels normally implies modifications to the source (structure), operational changes, or redesign of the physical configuration of the unit so as to relocate the noisiest components away from the most sensitive areas. Abatement of noise at the source is often a highly technical and complicated process because the energy emitted in the form of noise is a very small percentage of the total energy output.

Two general categories of noise sources are: vibratory/impact and aerodynamic. The mechanism of noise/vibration generation and basic principles of abatement for each of these two categories are described in the following sections.

### 2.1 VIBRATORY AND IMPACT SOURCES

Vibration usually results from excitation of resonances in the source components by cyclic or impulsive motion. Vibration may be caused by eccentric rotation, rapid changes in rotational velocity or impact on some parts of the source. The basic solution is to reduce the amplitude of vibration, and hence the energy available for acoustical radiation. Reducing the vibrating area attenuates the total sound power radiated, and changing the dominant frequency of vibration can alleviate the forcing conditions on the structure, or move the dominant components of the frequency spectrum to a region that is less sensitive with respect to perception by the human ear.

Amplitude reduction can be accomplished by keeping all contact surfaces of the source smooth and well lubricated. Where possible, all rotating parts should be dynamically balanced, and their mass reduced as much as possible. This is particularly important for fans.

Noise radiated from panels is made more intense by resonance. Radiation of this type may be controlled by vibration isolation of the particular source component. Damping or stiffening can be achieved by application of commercially available materials specially manufactured for this purpose.

Impact noise can be suitably reduced with the addition of some form of damping in order to apply the force more gradually and continuously. Noise caused by material handling (when dropping off parts on a hard surface is required) can be reduced by covering the surfaces with a damping material.

### 2.2 AERODYNAMIC SOURCES

Aerodynamic sources usually generate broad-band noise because of turbulent motions in gases. This category includes the noise produced by flames, jets, valves, fans and relatively high speed fluid flows.

The noise level is related to the turbulence intensity, which in turn is a function of the velocity of the medium concerned. Thus, it is often possible to make substantial reductions in the noise level by increasing cross-sectional areas and hence decreasing net flow velocities, and by eliminating right-angle bends or constrictions in ducting.

Noise abatement aimed at redesign of the source, may involve a large variety of design concepts depending on the type of source. Source redesign may involve, for example, inclusion of quieter drives, improved gears, larger fans or motors operating at lower speed, rubber or plastic bumpers to cushion impacts, reduced velocity of air jets, isolation of radiating surfaces from vibration surfaces, or application of damping materials to radiating surfaces.

In most cases where specialized equipment is involved, the manufacturer should be consulted before any steps are taken to abate the noise at source.

### 2.3 PROPER MAINTENANCE

Malfunctioning or poorly maintained equipment makes more noise than properly maintained equipment. Defective bearings, worn gears, slapping belts, improperly balanced rotating parts or insufficiently lubricated parts can considerably increase noise generated by a source. Similarly, improperly adjusted linkages or improperly set-up machine guards often make unnecessary contact with other parts and result in increased noise. Missing equipment guards can allow noise to escape unnecessarily. These types of noise sources share one characteristic: their noise emission can be readily controlled, though there is no simple way to predict how much noise reduction can be achieved through proper maintenance.

## 3. VIBRATION CONTROL AT THE SOURCE

Vibration control eliminates or reduces vibration at its source. In the discussion of benefits from proper maintenance, several vibration control techniques were already mentioned, including the balancing of rotating components and the elimination of unnecessary component contact. Vibration control may also include the use of vibration damping materials and mounting a vibration source on a special support which employs vibration isolators.

### 3.1 VIBRATION DAMPING

The vibration of metal panels, housings, enclosures or other members is a common source of high intensity noise. Reduction of resonant vibrational energy and subsequently the noise can be accomplished by the use of an effective damping material. Vibration damping materials when applied to vibrating surfaces cause the vibrational energy to be converted into heat energy. If this is accomplished, the need to absorb

and attenuate air-borne noise with sound absorption and barrier materials is reduced. Vibration damping materials are frequently applied to such structures as automobile doors, electric typewriter housings, air conditioning ducts, motor/compressor housings and grinder housings. Not only does the application of a damping material reduce the noise resulting from the vibration of the panel, it also leads to an increase in the transmission loss of the sheet. Single layer damping, sometimes called "free-field damping", is the most common way of damping metal chutes, staircases, kitchen sinks, pneumatic chutes, streetcars, buses, subway cars and a host of other products that have inherent vibration problems. This damping material is either sprayed or trawled on, or in some cases, brushed on. Damping sheet is also common and can be purchased with compatible adhesives installed. Damping sheet is used in office equipment, electronic cabinets and is often die-cut in specific shapes.

Another form of vibration damping is constrained layer damping which involves sandwiching a layer of damping material between the vibrating structure and an outer constraining layer. This type of damping relies on a sheer motion developed in the damping material to absorb vibrational energy. Its effectiveness is a function of temperature, vibrational frequency, thickness of the damping layer and thickness of the constraint layer. This type of damping finds application where structural members are quite thick (metal plates over 6 mm thick), or where a large vibration reduction is required.

## 3.2 VIBRATION ISOLATION

Vibration isolation does not reduce the amplitude of the vibrating force but prevents it from being transmitted from one object to another; for instance, a lathe to a bench. There are three major types of vibration isolators: metal springs, elastomeric mounts and resilient pads. Each type has advantages depending on the degree of isolation required, forcing frequency, weight of equipment, temperature, etc. Classification of vibration isolators is illustrated in Figure 9.1. Vibration isolators are commercially available. They are selected by specifying the weight to be supported, the deflection required and the lowest vibrating frequency of the unit to be isolated.

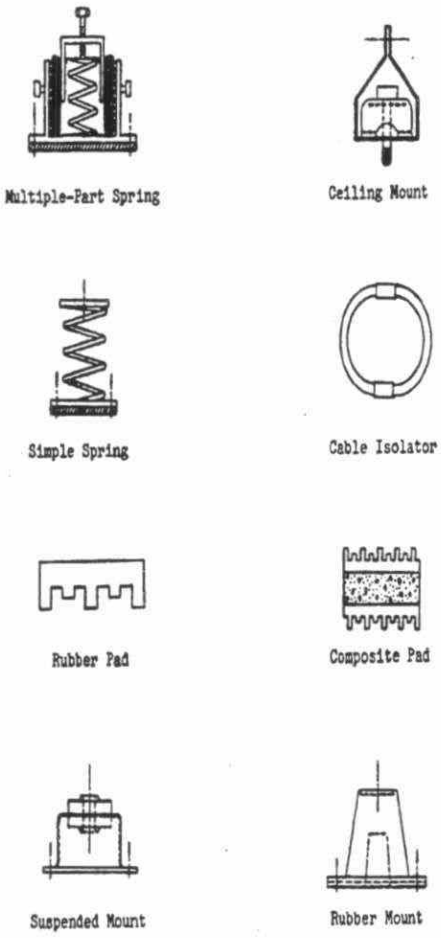


**Figure 9.1 Classification of Vibration Isolators**

A special problem arises with punch presses, drop forges and other sources of periodic impulsive vibration. Here the problem is to reduce the transmission of both the shock and the ensuing vibration.

### 3.2.1 Metal Springs

These have perhaps the widest use of all isolation types. They are particularly applicable where large, heavy equipment is to be isolated. The metal springs allow for large deflections and as such are especially effective where large loads and very low forcing frequencies are present.

### 3.2.2 Elastomeric Mounts

The elastomers are also very common vibration isolators. They can be easily moulded into practically any size or shape and their stiffness can be controlled over a wide range. Made of butyl rubbers, silicone, neoprene and combination of each, they are most suitable for applications that include small pieces of

equipment and relatively high excitation or forcing frequency. With regard to type of mounting, elastomers perform good under sheer loads as well as compressive loads.

In spite of their advantages over spring mounts, especially where space and weight are important, elastomeric mounts have limited durability and can deteriorate rapidly when exposed to corrosive acids, oil or solvents common in industrial environments.

### 3.2.3 Resilient Pads

Isolation pads are the simplest and most often used isolation mounts. They are available in natural rubber, synthetic rubber, blocks of cork, felt or fibreglass and combinations thereof. The major advantages of pad-type isolation are:

- They are easily inserted under equipment, eliminating tearing up the floor or inserting bolts.
- They are available in sheets of various thickness.
- They can be stacked to obtain large deflections and corresponding high levels of low frequency isolation.

The principal differences between the various pad materials are the stiffness or the natural frequency characteristics and the amount of damping each provides. A selection, however, is often based on such non-vibration considerations as abrasion resistance, load capacity, chemical resistance, tear strength or cost.

Natural rubber, for instance, has good isolation characteristics and fair temperature dependability, but poor aging and not as good chemical resistance as some synthetic materials. Cork pads in various densities have excellent aging characteristics, high stiffness and are widely used for isolating concrete foundations. Felt pads have excellent adhesion characteristics but are used exclusively in compression. Fibrous glass pads, in a highly compressed form, provide excellent vibration isolation for building floors. They have vibration characteristics very much like felt pads, are basically inert and highly resistive to industrial oils solvents, acids, etc.

## 4. NOISE ABATEMENT OF THE SOUND TRANSMISSION PATH

This method of noise control involves modification of the sound propagation path through application of acoustical materials, enclosures, barriers and silencers.

## 4.1 ACOUSTICAL MATERIALS

These can be divided into three basic categories:

- Absorbing Materials
- Barrier Materials
- Damping Materials

### 4.1.1 Absorbing Materials

Absorbing materials are generally resistive in nature, either fibrous, porous, or, in rather special cases, reactive resonators. Classic examples of resistive materials are fibrous glass, mineral wools, felt and polyurethane-type foams. Resonators include hollow core masonry blocks, sintered metal (honeycomb backed), etc.

Absorbing materials have high sound absorption qualities and generally soft porous surfaces. When sound waves come in contact with these absorptive surfaces, air travels in and out of the pores in the material because of the pressure changes produced by the sound waves. Frictional forces that result from this action convert the sound energy into heat, even though the amount of energy is quite small. Every time sound waves travel through the material at each reflection, energy is dissipated and there is a resulting reduction in the reverberant sound level of the particular enclosure lined with an absorbent.

Absorbing materials on room surfaces or inside equipment enclosures reduce reverberant sound, and thus reduce the effect of reflected sound. In this application, there are usually installed on or in the wall of the enclosure. It is very important to recognize that absorbents do not materially affect the transmission of sound; thus, they should never be used as shields or barriers or enclosure walls.

A note of caution with respect to the application of absorbing materials: It is only when these materials are used in close proximity to sound sources that they are effective as noise reduction measures.

### 4.1.2 Barrier Materials

Barrier materials may include wood, metals, glass, concrete, plastics or any combination of thereof. To be effective, barrier materials should have one basic common property: dense mass. The most

effective barrier materials also have a high degree of internal damping. Sheet lead is the best example of dense massive barrier material.

The sound isolation properties of materials are stated in terms of transmission loss. As with absorption, the concept of energy flow is used; here it is the energy transmitted through the material, relative to that flowing toward it.

Transmission loss of a material is dependent on the frequency of the sound, the angle of incidence of the sound waves and the mass of the material.

**The transmission loss increases by 6 dB each time the weight is doubled and 6 dB each time the frequency is doubled.**

To provide maximum acoustical effectiveness, it is necessary that an enclosure or a barrier be absolutely air-tight. Even a slight opening as small as 0.8 mm in the structure will cause noticeable degradation of noise abatement effectiveness.

### 4.1.3 Damping Materials

Are usually relatively thin coatings of plastic polymers, epoxy or glue which can be adhered to sheet metal panels, gear, machine parts, etc.

In a summary of discussion regarding acoustic materials, it must be emphasized that for most noise control applications, no single material type is optimum, but rather a combination is usually preferred. A good example of typical application is a machine enclosure panel made of composite materials. Here absorbing materials are used to reduce internal reverberant sound build-up, dense barrier materials provide acoustical isolation, and damping materials increase the transmission loss of the barriers.

## 4.2 ENCLOSURES

Complete or partial enclosure is often the simplest and most effective measure for solving a noise control problem when adequate source control is not possible. The enclosure walls are typically constructed of carefully balanced combination of absorbing, damping and insulating materials incorporated into modular units.

The provision of absorption is important because it prevents high reverberant sound levels due to reflections within the enclosure walls, and thus minimizes the wall vibration and the resultant radiation of noise.

## 4.4 SILENCERS AND MUFFLERS

Silencers and mufflers cover a wide range of very effective noise reduction devices. There is no technical distinction between a muffler or silencer and the terms are frequently used interchangeably. Despite a wide range of silencer configurations, these devices can be categorized into three distinct groups:

- **Absorptive silencers**

  contain either fibrous or porous materials and depend on the absorptive properties of these materials to reduce noise.

- **Reactive silencers**

  contain no absorptive materials but depend on the reflection or expansion of sound waves with corresponding self-destruction as the basic noise reduction mechanism.

- **Dispersive silencers**

  noise reduction usually comes from diffusing a high velocity gas flow into smaller lower velocity streams.

Some silencers combine the elements of two or more types for extended performance. With a basic understanding of the acoustical properties of each type, a silencer or combination of silencers can be usually selected which will effectively provide noise reduction regardless of the character of the noise. Difficulty generally is found not with finding silencers with adequate acoustical performance but with selection of proper size, weight, aerodynamic pressure losses, etc.

### 4.4.1 Absorptive Silencers

These are widely used in acoustical treatment of installations where large volumes of air or gas are moved at relatively low static pressures. The noise reduction in this type of silencers is accomplished through use of a blanket of absorptive material. The absorptive coefficient of the material will increase with thickness. This type of silencer is very useful for broad-band noise attenuation, and is especially effective at high frequencies. The absorptive blanket may require a special protective facing if placed in a duct with a high velocity or high temperature air stream.

The absorptive silencers may be applied in the form of lined ducts, parallel baffles, lined bends, plenum chambers, acoustic louvres or motor and burner silencers.

### (a) Lined Ducts

A very simple form of duct silencer can be fabricated by lining the interior of the duct with absorptive materials. The amount of attenuation is dependent upon the frequency of sound, length of the duct, the type and thickness of the absorptive lining, the presence or absence of facing material and the cross-sectional area of the air-stream.

Typically, the lining material chosen is acoustical quality fibrous glass 25-75 mm thick.

### (b) Parallel Baffles

These devices are essentially extensions of the lined duct. An example of parallel baffles is shown in Figure 9.2.

Basically, the parallel baffle type duct silencer consists of an aerodynamically streamlined entrance and exit with perforated walls backed by highly absorptive acoustical material. The absorptive material is usually fibrous in texture, either glass or mineral wools. The acoustical performance of parallel baffles depends primarily on thickness of the absorptive material, spacing of baffles and length of baffles.

(1) Galvanized steel
(2) Bonded long fibre, acoustical fill
(3) Galvanized sheet metal casing
(4) Aerodynamically designed air passages

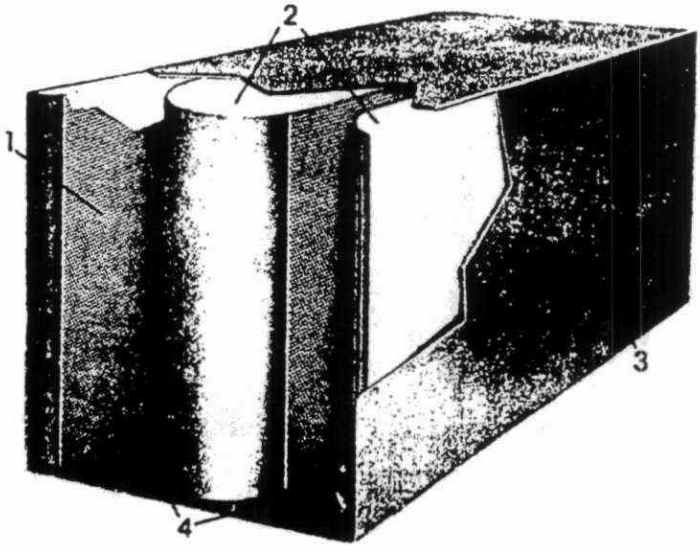


**Figure 9.2 Typical Parallel Baffle-type Silencer**

### (c) Plenum Chambers

These units are large volume chambers which interconnect two ducts as shown in Figure 9.3.

The interior of the chamber is lined with absorptive material, and thus part of the sound energy which enters the chamber is absorbed due to multiple reflections within the unit.

Although classified here as an absorptive silencer, the plenum chamber also acts as a reactive device, owing to the discontinuities that exist at both the inlet and outlet of the chamber.

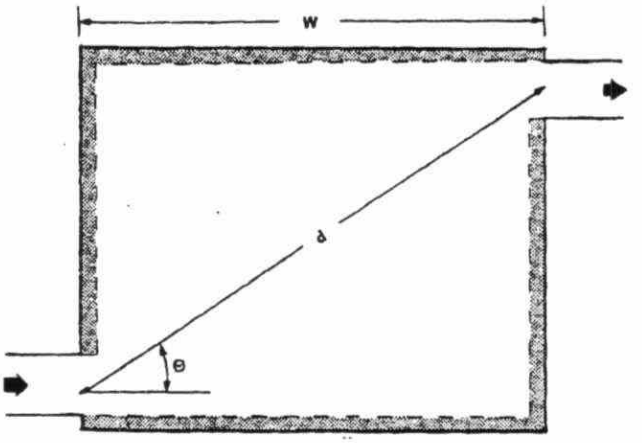


**Figure 9.3 Acoustically Lined Plenum Chamber Silencer**

Typically, the attenuation ranges from about 10 dB at low frequencies to 20 dB in the frequency range above 1 kHz. This performance can be improved by increasing the thickness of the absorptive lining, blocking the direct line of sight from chamber inlet to outlet, either through the use of a sound absorptive panel, or by using multiple chambers, and by increasing cross-sectional area of the chamber for a given size of inlet and outlet duct.

### (d) Acoustical Louvres

The acoustical louvre is another form of parallel baffle as shown in Figure 9.4.

In this configuration, each louvre blade is filled with absorptive material. With the underside of the blade constructed of perforated sheet

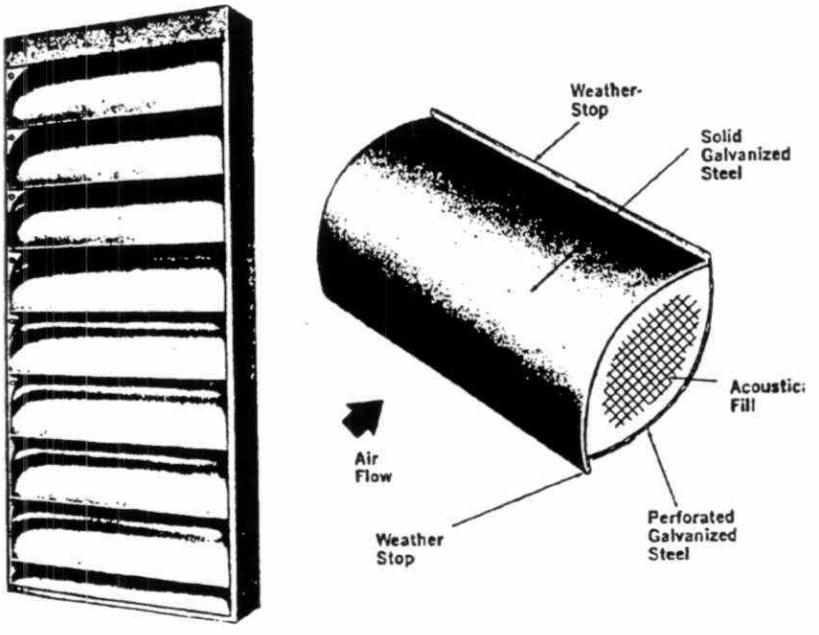


**Figure 9.4 Basic Construction Features of Acoustical Louvres**

metal, noise passing through the air passage is absorbed in a manner analogous to a parallel baffle. The acoustical performance of louvres is somewhat limited, especially in the low frequency range.

There are many applications of these louvre units such as cooling tower inlets, mechanical room inlets, fresh air intakes, external building wall penetrations, etc.

### (e) Motor and Burner Silencers

The noise from electric motors is dominantly due to the cooling air fans. To control the fan noise, an absorptive type silencer can be mounted on the end bell of the motor as shown in Figure 9.5.

Here the cooling air enters the silencer through the end screen, passes through the silencer and exits over the motor-cooling fins. These air passages are typically constructed of absorptive materials which reduce the fan noise as it passes through the silencer.

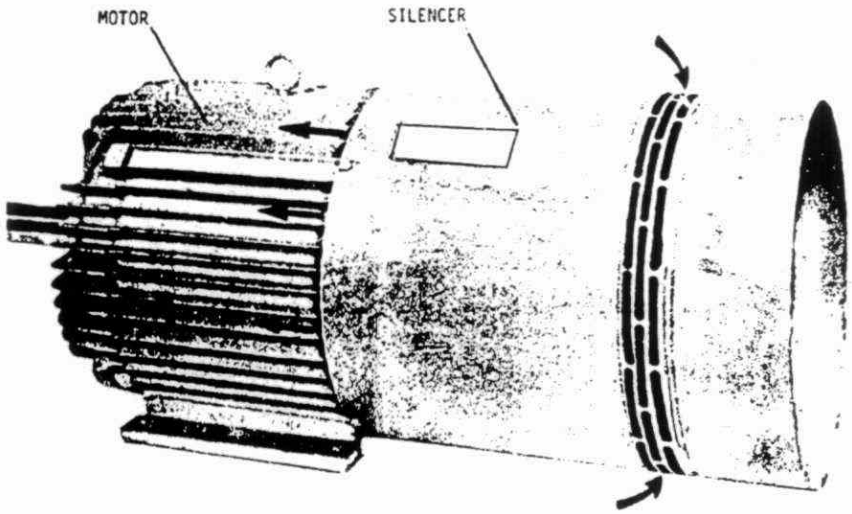


**Figure 9.5 Motor with a Fan Silencer Installed**

The attenuation of these devices is typically in the range of 6 to 10 dB at frequencies of 1 to 8 kHz where the fan noise is concentrated.

Other common applications of motors that can be treated with this type of silencers include drive motor for pumps, compressors, blowers, fans, centrifuges, etc.

Silencers of a similar design can be applied to the inlets of gas or oil burner intakes such as are common in the petro-chemical industry and for drying oven applications in the areas of food processing.

## 4.4.2 Reactive Silencers

Reactive-type silencers generally consist of one or more expansion chambers wherein, as sound passes through, attenuation is achieved through reflective-self destruction. Probably the most common example

of a reactive silencer is the automobile muffler. The acoustic performance of reactive silencers is rather selective spectrally and, in most applications, the silencer must be designed or tuned to the discreet frequency character of the noise.

They are also used for applications where the gas stream is dirty and would perhaps block or clog an absorptive silencer. They are economical and have little pressure drop. However, their performance deteriorates at high frequencies when used with large diameter ducts.

Typical examples of reactive silencers application include internal combustion engines, compressors, rotary positive displacement blowers, vacuum pumps, etc. The reactive silencers may be applied in the form of expansion chambers, cavity resonators and pre-fabricated multi chamber reactive silencers.

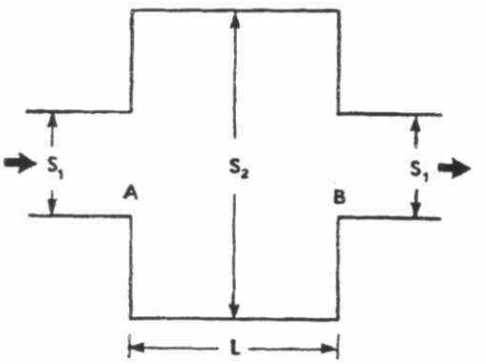


**Figure 9.6 Single Expansion Chamber Silencer of Length L and Cross-sectional Areas $S_1$ and $S_2$**

### (a) Expansion Chambers

An expansion chamber, as shown in Figure 9.6, has discontinuities in cross-section at both the inlet and outlet. The design of the chamber is dependent upon the wavelengths of the incident sound, i.e. the chamber length is chosen so that the device is "tuned" to cancel a very narrow band of frequencies and thus acts as a notch filter.

Because expansion chambers are frequency selective, they are ineffective in reducing broadband noise. However, a number of expansion chambers can be employed in series and their frequencies of maximum attenuation staggered to yield an overall system with somewhat broadband characteristics.

### (b) Cavity Resonators

The general form of a cavity resonator is shown in Figure 9.7.

The air within the cavity acts as a spring which is forced in and out of the cavity, by way of the neck, by the periodic air flow (which acts as a mass). The cavity and the neck are designed to be tuned or resonant to a particular low-frequency, and thus this device is a very selective low frequency narrow-band absorber.

Because the problem of controlling low frequency noise is very difficult, this type of absorber can be extremely useful.

Although this device has a definite absorption peak in the low-frequency range, this peak can be flattened so as to extend into the high frequency range by filling the cavity with some form of absorptive material.

The attenuation of a wide range of frequencies may also be accomplished by employing a number of these devices each tuned to a different frequency within the range. An example of a cavity resonator frequently used in the construction industry is that formed by cutting slots in a standard concrete block as shown in Figure 9.8.

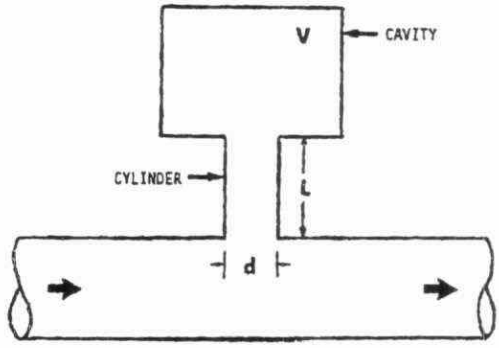


**Figure 9.7 Major Elements of a Cavity or Helmholtz Resonator**

When the blocks are closed at the top, they can be stacked to form a wall of cavity resonators. Their performance can be improved by filling the cavities with porous material. This type of resonator, in contrast to the soft porous materials, is extremely ragged and durable. A significant reduction in reverberant sound energy can be accomplished in a carefully selected range of frequencies using this type of resonator.

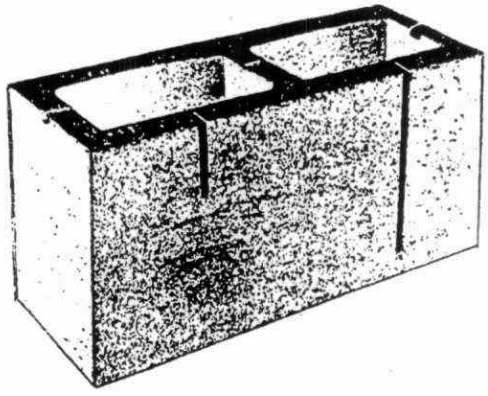

**Figure 9.8 Example of Slotted Hollow Core Masonry Blocks**

Examples of application of such hollow-core masonry blocks include: interior walls of diesel engine rooms, partial enclosures for outdoor transformers, etc.

### 4.4.3 Dispersive Silencers

These types of silencers are used mainly in the control of noise from small high-pressure relief or exhaust valves such as found in pneumatic controls, solenoid valves, air cylinders, clutches, brakes, air-driven hand tools, etc. The noise source is usually high-velocity air exhausted as a burst to the atmosphere.

With a dispersive silencer installed over the exhaust vent, the high-velocity air is released into an expansion chamber and subsequently dispersed at a much lower velocity through porous sintered metal slots.

Shown in Figure 9.9 are some commercially available dispersive silencers. These silencers are usually available with standard pipe thread connectors for easy direct installation and can be mounted in any orientation.

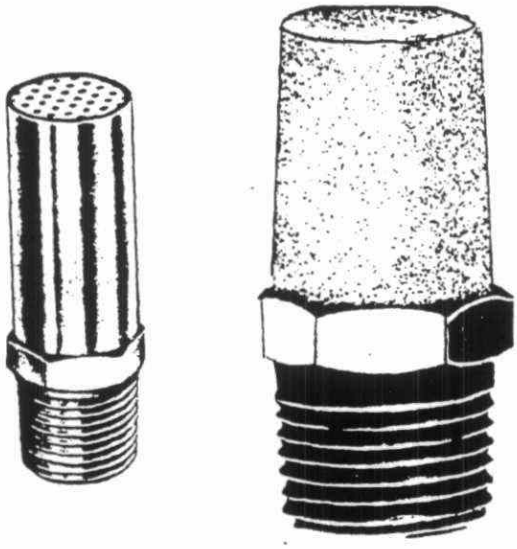

**Figure 9.9 Examples of Dispersive Silencers**

In final summary, where air and gas is either moved, conditioned or vented, some form of noise control is usually required. Areas such as these are common not only in industry but in our daily and recreational living. As such one recognizes that silencers provide very effective means of noise control.

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